

A black and white photograph of a nuclear explosion's mushroom cloud. The cloud is massive, with a bright, billowing top and a thick, dark column of smoke and debris rising from the ground. The background is dark, making the white and grey of the cloud stand out.

NUCLEAR WAR

Donald B. Kraybill
John P. Ranck

and
Lancaster
County

A black and white photograph of a nuclear mushroom cloud. The cloud is large and billowing, with a bright, glowing core at its base. A dashed white line is drawn across the image, starting from the bottom left, curving upwards and to the right, and then curving back down towards the bottom right. The line passes through the lower part of the mushroom cloud. The background is dark and cloudy.

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NUCLEAR WAR and LANCASTER COUNTY

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FOREWORD

Humankind in the past has been devastated by such diseases as smallpox, diphtheria and typhoid fever. In 1918 the United States lost 500,000 people and the world 22 million to influenza. Cholera, bubonic plague, and tuberculosis have ravaged humankind for centuries. Ironically, the technology which has helped us gain control of infectious disease now threatens us with a much greater menace to public health - thermonuclear war. This danger has aptly been called "The Final Epidemic." In a full scale nuclear conflict as many as 140 million Americans and 120 million Soviets could be killed. The entire world would be changed with survivors literally facing a medieval existence or worse.

At every level we want to deny this international danger, partly because thinking about a nuclear holocaust is so painful and partly because the statistics usually have no meaning for the reality of our daily existence. This monograph clarifies the effects of a nuclear attack on our local level and brings the statistics into abrupt and startling focus. The authors bring us images that we can relate to by describing the probable effects of a nuclear war on Lancaster County. In a superbly referenced text, they explain why we are a possible target and describe what could happen to us in the event of a nuclear attack - a blast that virtually destroys all of Lancaster City. Clearly there is truth in the adage "the survivors could well envy the dead."

It is a terrifying scenario! Yet we must not turn away from it, for nuclear war is a frighteningly real possibility. Indeed, the magnitude of the potential devastation is all the more reason to urgently find a solution. As has been the case with every other major threat to the health and well being of humanity, the only effective solution is prevention.

This monograph should be read by all Lancastrians, and especially by those we depend on to help us in times of great trouble - clergy, physicians, community leaders, civil servants. None of us dares have illusions about the nature of such a catastrophe. Yet the scope of this study is broader than Lancaster. The effects described here could be seen in every major community of this nation as well as in other nations involved in such a conflict.

Read it, and then bring whatever resources and strengths you can to help prevent "The Final Epidemic."

James Eastman, M.D., President
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INTRODUCTION

FACING UP TO NUCLEAR WAR

For the most part, we go about our daily lives working, playing, establishing friendships, and generally enjoying life with little thought that tomorrow might not be like today. Our lives are built upon regularity and predictability. We plan vacations, schedules, social events and careers. We conceive children and expect that we will see them reach maturity. Occasionally, however, this regularity of life is punctuated by the death of a close friend or family member. Magnificent plans are abruptly terminated, children are left without parents, and friendships evaporate. Death and separation are not pleasant, but they are real. In one way or another, each of us has had to deal with the deaths of others as well as with the prospect of his own death.

A few persons become so obsessed with the fear of their own impending or eventual death that it pervades all of their life. They are psychologically paralyzed and unable to enjoy their own or others' lives. At the other extreme, some respond by denying the reality of death, pretending that things will always be the same. Such fatalists, whether of the "when my time is up, that's it" or of the "leave it in the hands of God" variety, deny the reality of death and fail to deal constructively with it. Others overcome the shock and fear of death by depersonalizing it through professional, technical, or clinical means.

Most of us, however, respond to death neither by obsession, nor denial, nor by professional detachment. We do ponder death from time to time, and we may modify our living patterns in response. We give up smoking. We fasten our seat belts more regularly. We change our eating and exercise habits. We take out life insurance to provide for our families if necessary. We live each day with a new awareness of the uncertainty of life, thankful for the simple pleasures and joys it provides. In many ways, our response to the prospect of death enriches our lives.

Like death, nuclear war is not pleasant to contemplate. We have had only two occasions to witness the effects of nuclear weapons and have found those to be so horrible and so far beyond our usual experience that they are nearly incomprehensible. At least 75,000 people were killed outright by the blast at Hiroshima, and another 75,000 suffered injuries from burns and blast effects. Others perished painfully from severe doses of radiation. Firestorms with winds raging hundreds of miles per hour devoured the people and buildings in a 4 square mile area of Hiroshima. In Nagasaki, over 60,000 people were

killed and injured by one nuclear bomb. Current estimates of the number of U.S. fatalities alone in a large scale nuclear exchange between the U.S. and the Soviet Union range from 20 to 165 million persons. The images are grotesque.

In the thirty-six years since the U.S. bombings of the Japanese cities, our memories of these tragedies have dimmed and a new generation has grown up without memories of these events. Since 1945, the magnitude of the death and destruction possible by nuclear weapons has increased hundreds of fold. As if this were not enough, the probability that the nuclear genie will again be unleashed has also increased. Yet for the most part, we have responded to this possibility by psychological avoidance, secure in the belief that nuclear war is so horrible that God (or the President, or the military) will never allow it to happen, or that if it does, we will all be dead and nothing will matter anyway.

Avoidance and denial have not been altogether unreasonable responses for much of this time. Since the Soviet Union acquired a substantial nuclear arsenal in the early 1950's, a balance of terror has persisted between the superpowers. Each side has been deterred from using its nuclear weapons because of the knowledge that even after an initial strike, the other side would still possess enough bombs to devastate utterly the attacker's cities and industries in return. Further, there is no effective defense against these weapons. Thus, the civilian populations of both nations are held hostage in this international stalemate.

It is reasonable to argue that this policy of deterrence by threat of massive retaliation has been the principal reason that nuclear weapons have not been used since 1945. We believe, however, that recent events have so eroded the stability of this balance of terror that the possibility of nuclear war is no longer remote. Policies, strategies, and weapons systems on both sides are designed increasingly toward fighting and winning a nuclear war rather than toward avoiding such a war.

Several events have changed the character of deterrence. Multiple, independently-targeted warheads have been installed on many of the missiles of both sides. This allows a single missile to deliver 3 to 10 warheads to separate targets. At the same time, the accuracy of missiles has been improved so that 50 percent of the newer missiles can be expected to fall within 200-300 yards of their targets, even when launched a continent away. Multiple warheads and increased accuracy have changed the deterrence equation so that both sides may now contemplate the possibility of destroying virtually all the enemy's land-based missiles in their silos by using only a fraction of its own missiles. In times of international crisis, this possibility of striking the enemy's missiles first, before he does the same thing, could be a very tempting invitation to begin the holocaust that was

previously unthinkable. This is not fantasy. Our military planners take this threat seriously enough that we have been asked to appropriate tens of billions of dollars for the MX missile system in order to protect our present land-based missiles from this type of attack. Further, Presidential Directive 59, signed by President Carter on July 25, 1980, called for increasing the ability of the U.S. to fight a "prolonged but limited nuclear war" which would involve attacking "selective targets" such as military installations and weapons. This confirms that deterrence by threatening the Soviet population is not our only strategic policy (if, indeed, it ever was) and that much of our military planning is directed toward fighting rather than preventing a nuclear war.

Members of Congress and the Department of Defense tell us that U.S. intelligence indicates that Soviet policies are also directed toward winning a nuclear war. Perhaps the Soviets have concluded that a nuclear war may well be inevitable and therefore believe it is prudent to plan to come out of such a confrontation in the best condition possible. Or perhaps this indicates an intention to launch such a war, in the belief that by doing so, they can shift the balance of world power substantially in their favor, even at a dreadful cost. Regardless of our perceptions of the Russians, we are being told that they are planning to fight (and win) a nuclear war and, therefore, we must also plan to fight (rather than prevent) nuclear war.

World-wide military expenditures continue unabated and are approaching one and one-half billion dollars per day. Not only have we failed to negotiate a ceiling on the number of nuclear weapons, but we are rapidly increasing military spending while cutting our expenditures on education, health care, social services and foreign aid. The number of strategic warheads in our own arsenal already exceeds 10,000; yet there are only 200 or so Soviet military and industrial centers of any possible strategic importance. This number of warheads does not include the 22,000 tactical nuclear weapons planned or already in place in the NATO forces of western Europe and elsewhere around the globe. Most of these tactical weapons have more power than the bombs dropped on Hiroshima and Nagasaki. One of the proposed MX missiles could carry 10 warheads, each 20 times more powerful than the Hiroshima bomb, and aim them at 10 different targets. One U.S. submarine alone can deliver 224 warheads, each at least twice the size of the Hiroshima bomb, at 224 targets. The new Trident submarine soon to be deployed will have the capacity to deliver 408 warheads to that number of separate targets.

We have developed an overkill potential that has no relation to preventing (or even fighting!) a nuclear war, but is related only to being superior, no matter what the cost or meaning of superiority. The Soviet Union has joined in this venture and is equally guilty. Regardless of fault, continued production and deployment of this enormous number of nuclear weapons in the hands of more and more persons throughout the world increases the possibility that nuclear weapons will

be used, either through miscalculation, accident or by intention. All of this means that the possibility of nuclear war is very real.

Nuclear weapons seem destined to soon fall into the hands of governments and terrorist groups with great instability and little to lose. In the absence of an effective treaty limiting other nations from acquiring nuclear weapons and forcing the superpowers to negotiate the reduction of their stockpiles, nuclear weapons remain a symbol of world power. It is widely acknowledged that Israel either has or could very quickly assemble nuclear weapons. There is much talk of Pakistan's acquiring an "Islamic bomb." After Israel and the Arab states, can Egypt, South Africa, Brazil, Argentina, South Korea, etc. be far behind? Nuclear weapons technology, though moderately expensive, is not inherently difficult.(1) Nuclear materials can be acquired from power plants or reprocessing facilities by theft or direct assault. We should not be surprised if a terrorist group in the U.S. or abroad, such as the PLO, the Baader-Meinhof gang, or a guerilla force in any of a number of countries threatens to use or actually uses nuclear weapons in the next few years.

We are not alone in our assessment that the possibility of nuclear war has increased significantly during recent months. Defense analyst, Richard Garwin, at a symposium of the American Association for the Advancement of Science in January 1981, responded to the question of the probability of nuclear war by the year 2000 as "at least 50-50, with a somewhat larger probability for limited nuclear war." The Bulletin of the Atomic Scientists, which for 35 years has maintained as a part of its cover a doomsday clock indicating its estimate of the peril, advanced the hands of the clock from nine minutes before midnight to seven minutes before midnight in January 1980, citing the increasing irrationality of national and international actions. In January 1981, the clock was advanced to four minutes before midnight because...

the world seemed to be moving unevenly but inexorably closer to nuclear disaster...

The somewhat flawed but carefully balanced and patiently negotiated second phase of the Strategic Arms Limitation Treaty with the Soviet Union appears to be out the window. Nuclear weapons - more and more unambiguously aimed at war-fighting rather than war-deterrence - are now being rapidly deployed by the East and the West in Europe. The Russian SS-20 and the U.S. MX blatantly announce a new race in

(1) In 1978, Howard Moreland, a free-lance journalist with no access to classified government information required only six months to uncover, according to the Justice Department suit in the Federal District Court, "the basic design concepts and various design features of U.S. thermonuclear weapons."

improved missile accuracy and mobility, heralding the acceptance of counterforce first-strike by both sides.

These ominous signs of deterioration are cast into starker relief by the flat unwillingness of either the United States or the Soviet Union to reject publicly, and in all circumstances, the threat of striking the other first. Both sides willfully delude themselves that a nuclear war can remain limited or even be won. In 1980, both sides officially declared nuclear war "thinkable."

At the same time, there has not been progress, but further retrogression in the responsibility shown by the developed part of the world toward the underdeveloped two-thirds...The betrayal is now made official by the publicized resolve of the two superpowers to expand their military programs beyond the already astronomical global figure of \$600 billion per year. Meanwhile large areas of the developing world remain crippled by poverty that soaring energy costs have only intensified.(2)

Most discussions of the arms race remain up in the sky of abstraction with vague notions about "winning" and "superiority" in far away places. The vocabulary is professional, detached, ambiguous and meaningless to most of us. The realities of the arms race must be brought down to earth and described in specific and concrete terms so that we can unmask and understand without any doubt the potential human suffering - even for Lancaster Countians - that accompanies this drive toward undisputed superiority.

All of us must consider the possibility of nuclear war more seriously than at any time in the past. We must find more appropriate ways of incorporating this reality into our lives. Psychological avoidance is no longer appropriate or helpful. It is difficult to imagine death and destruction of a magnitude that has never been witnessed before, but we must try - and we must do so in a context that is personal and that relates to our homeland and to our families. We can no longer use the sanitized terminology of technicians in which missiles targeted to destroy cities and kill people become simply "countervalue weapons." Nuclear war, like death, only becomes real to us when it involves those we know and love.

(2) Bulletin of the Atomic Scientists, January 1981, p. 1.

It is for these reasons that we have described the probable effects of nuclear war on Lancaster County. This Garden Spot is our home and we care deeply about its survival and future. For some of us, Lancaster County has been home for a long time. We can trace our lineage back over seven generations, house by house, and farm by farm, to the spot where our immigrant ancestors settled. Others have arrived in Lancaster County more recently. Regardless of whether we have lived here seven years or seven generations, Lancaster County is our home. We cherish the places and spaces that shape our heritage and we want to pass them on to our children. The historical landmarks, the rolling hills, and the meandering Conestoga all mold our sense of identity as a people and provide continuity between yesteryear and today. The memories they engender make us who we are. But the world is filled with Lancaster Counties; every spot on Earth is part of someone's heritage. Emotional ties and memories are universal. Only the names are different. Can we care less deeply about others' homelands, others' heritages, and their children?

The funeral we are about to describe is not pleasant, and the invitation to share the agonizing thoughts and images we will present is not extended lightly. One of the contradictions of the Cold War is that reciting well-known place names and population numbers seems irreverent, while building and stockpiling weapons to cause their incineration is done with great respect and patriotic fervor. There are not sufficient superlatives to describe the obscenity of the death and destruction triggered by global war, nor for the revulsion we feel when considering it in terms of people and places rather than in sanitized technical terms. Yet describe it we will in the hope that this sobering confrontation with what is possible and according to some, even likely, will help us to respond in new ways to avert a disaster which, unlike death, need not be inevitable. By considering the possible effect of nuclear devastation on ourselves, our families, and our homeland, and extending these images to other families, and other homelands throughout the world, can we return from the funeral with some sense of resolve that this is not what we want for our children? Will we be moved to strive as individuals and as a nation to discover new policies, strategies, and means for the conduct of international affairs that offer some hope of lifting this pall from our future?

CHAPTER 1

NUCLEAR STRATEGIES AND LANCASTER

Is there a Soviet Intercontinental Ballistic Missile (ICBM) somewhere with the coordinates N 40:02:24, W 76:18:23 (the latitude and longitude of Lancaster City) already entered into its guidance system? If it exists, under what circumstances might such a missile be launched? Is it significant that the Federal Emergency Management Agency's map of High Risk Areas for Civil Nuclear Defense Planning shows much of Lancaster County in bright red (Figure 1.1)? Our perception is that in



figure 1.1.
Nuclear Attack High-Risk Areas Defined by Federal Emergency Management Agency

spite of RCA with its infrared sensing and imaging equipment, Hamilton Technology with its bomb fuzes, and the 50 or so other Lancaster County industries operating under Department of Defense contracts, Lancaster is of only marginal strategic importance.(1) Are these perceptions accurate? In the event of a war with the Soviet Union, is Lancaster County directly threatened, or will we suffer only because of our proximity to the Philadelphia/Wilmington petroleum refineries, the Port of Baltimore facilities, the airfield and state government at Harrisburg, the national government at Washington, and the military command facilities at Camp David/Fort Ritchie in Maryland? Undoubtedly the answer depends upon the scale of conflict and the context in which a nuclear war might be launched.

NUCLEAR ATTACK SCENARIOS

American defense policy, for many years, has been built around a triad of strategic nuclear forces: land-based intercontinental ballistic missiles (ICBM's), long-range bombers, and submarine-launched ballistic missiles (SLBM's). Each leg of this triad enjoys its own type of protection against attack, and each alone could destroy 75 percent or more of the Soviet industrial target base even after being hit by a massive Soviet nuclear attack. Any two of these systems could destroy some 90 percent of the Soviet industrial target base even after a massive Soviet nuclear attack.(2) Together, these three weapon systems and the plans for their use are designed to assure the Soviet Union or any adversary that an attack on the United States or its allies is guaranteed to result in a total defeat of objectives and such a massive destruction of its cities, industries, and military forces that no outcome could represent a victory.

This deterrence by assured destruction makes a massive surprise attack by the Soviet Union against American cities (whether including Lancaster or not) quite improbable. We may not understand Soviet ideology or the mentality of the Soviet leaders, but it is clear that the Soviet Union is not bent upon suicide. However, to say that the Soviet Union or the United States would not launch a surprise attack against the other because such an attack would be suicidal does not mean that there are no circumstances under which each might perceive its national interests so threatened that it might not risk nuclear war to gain some objective - even knowing that tens of millions of its own people would die.

 * (1) In 1980, over 50 Lancaster County industries had prime contracts with the Department of Defense for \$10,000 or more, which totaled about 40 million dollars. This amount might double if defense-related sub-contracts could be identified and included.

(2) The Congress of the United States, Congressional Budget Office, Retaliatory Issues for the U.S. Strategic Nuclear Forces, U.S. Government Printing Office, June 1978, p. xi.

Many civilian and military leaders believe that improved technical capabilities might lead the Soviet Union to launch a preemptive first strike against U.S. nuclear forces in a time of international crisis. (Depending upon which side you are on, such action might not seem outrageous. Opinion in this nation, though not throughout the world, largely supported Israel in its preemptive strike against the Iraqi nuclear facilities it deemed potentially threatening to its security.) A background paper prepared for the U.S. Congress by the Congressional Budget Office identifies three possible Soviet objectives for such a counterforce first strike:

1. To reduce U.S. options in a limited nuclear war by an attack on the U.S. ICBM force.
2. To shift decisively the balance of nuclear power in favor of the Soviet Union by an attack on U.S. strategic forces.
3. To limit damage to the Soviet Union in an all-out nuclear war by an attack on U.S. strategic forces.(3)

Although the third possibility may be the most likely, the Department of Defense has been particularly concerned about the first - the possibility that the Soviet Union might launch an attack against U.S. land-based ICBM's (a "surgical" first strike, killing only 3.2 to 16.3 million Americans), leaving massive retaliation against Russian cities as our only response. We would probably not make this response as long as our own cities remained intact and the Soviet Union still held a reserve force of missiles capable of destroying them. For these reasons, defense policies have turned to protecting the land-based ICBM's (the mobile MX missile system) and to strategies and weapons systems designed to destroy Soviet missiles (counterforce) rather than their cities and industries (countervalue).

From an American point of view, such policies might seem altogether prudent, rational, and stabilizing. From the Soviet point of view, however, such action might look very different. Because the Soviet Union has only a small portion of its nuclear forces deployed in bombers and submarines and is almost entirely dependent upon its land-based ICBM's for its defense, any U.S. move which threatens its ICBM's in their silos must appear extremely provocative. A U.S. weapon intended only for second-strike retaliatory purposes would look identical in Soviet eyes to a first-strike weapon. One possible response to such a threat would be the adoption of a "launch on warning" or "tripwire" policy to prevent the loss of missiles in their silos. Except for the fraction of strategic nuclear weapons deployed as ICBM's, this argument

(3) The Congress of The United States, Congressional Budget Office, Counterforce Issues for the U.S. Strategic Nuclear Forces, U.S. Government Printing Office, January 1978, p. 5.

applies to both sides and encourages an American "launch on warning" policy. This reasoning is at the heart of the debate as to whether counterforce policies stabilize or destabilize the nuclear arms race.

We could, and defense analysts do, go on spinning scenarios for possible nuclear wars in great detail. In The Third World War, for example, General Sir John Hackett and other retired NATO generals describe a general war in Europe beginning with a plausible Soviet invasion of West Germany and ending with the destruction of Birmingham in England and Minsk in the U.S.S.R.(4) Then both sides reconsider the cost and retreat from the brink of Armageddon. Most such scenarios assume a degree of restraint by each side in response to some action by the other. The Soviets, however, never seem to make the same presumptions, and are either amused or dumbfounded by such Western ideas as "countervalue," "disabling first strike," or "limited nuclear war." Thus, Hackett's and other similar scenarios notwithstanding, there remains in most quarters great skepticism that nuclear war, once started, could ever be controlled in any way.(5)

Considering all these uncertainties, where does this leave Lancaster? We believe that the following conclusions are valid.

1. A massive surprise attack on American cities, which might or might not include Lancaster, is unlikely.
2. Regional conflicts will continue in Eastern Europe, the Middle East, Africa, Latin America, and elsewhere around the globe. By some curious cold-war logic, the United States and the Soviet Union will regard many of these conflicts as threatening to their national interests. Both superpowers will go to great lengths to display solidarity with allies, and to demonstrate their world-wide power. Actions and intentions which involve posturing for audiences at home and abroad are bound to be miscalculated and misunderstood by both sides. Without previous design, any such regional conflict could quickly escalate into a strategic confrontation between the Soviet Union and the United States.

(4) New York: Macmillan, 1979.

(5) Secretary of Defense Harold Brown, in his annual report to the Congress, on January 29, 1980 stated, "My own view remains that a full-scale thermonuclear exchange would constitute an unprecedented disaster for the Soviet Union and for the United States. And I am not at all persuaded that what started as a demonstration, or even a tightly controlled use of the strategic forces for larger purposes, could be kept from escalating to a full-scale thermonuclear exchange." Department of Defense Annual Report, Fiscal Year 1981, p. 67.

3. Multiple warheads and increased accuracy of missiles are combining to make a disarming first strike in time of great stress a tempting option for either the Soviet Union or the United States.
4. The proliferation of nuclear weapons to less stable governments and the ease with which terrorist groups could acquire nuclear weapons will both weaken the ability of the Soviet Union and the United States to control regional conflicts and increase the probability that nuclear weapons will be used in an international confrontation in the next few years.
5. Once nuclear weapons are used, massive exchanges of thermonuclear warheads cannot be ruled out.

Taken together, these factors steadily increase the probability that nuclear weapons will be used. Estimates by responsible analysts that nuclear war by the end of the century is more likely than not cannot be disregarded. *

LANCASTER'S FATE

In the event of a nuclear exchange between the Soviet Union and the United States, how would Lancaster fare? Let us try to answer the question by examining the strategic force levels of both sides and making some very conservative assumptions. The numbers of ICBM's, SLBM's, and bombers with intercontinental range, together with the number of thermonuclear warheads they are capable of delivering are given in Table 1.1. There is wide agreement for these numbers in many unclassified government documents as well as in the publications of the International Institute for Strategic Studies (London) and Stockholm's International Peace Research Institute. Although the numbers are constantly changing as new systems are added and old ones are phased out, such small changes make no difference in our basic argument.

Rather than consider an attack against cities and people, let us assume that nuclear weapons are first used specifically against other nuclear weapons and militarily important targets. Consider the result of a Soviet first strike against U.S. missiles followed by a U.S. retaliatory strike against Soviet missiles. Alternatively, consider an opposite missile-trading scenario in which the U.S. strikes first.

Table 1.1. Soviet and United States Strategic Force Levels

		Delivery Vehicles	Nuclear Warheads

USSR	ICBM's	1398	5608
	SLBM's	950	1470
		----	----
	Total	2348	7078
US	ICBM's	1054	2154
	SLBM's	656	5440
	Bombers	340	2560
		----	----
	Total	2050	10154

The U.S.S.R. could attack the 1054 U.S. ICBM's, allowing two ground bursts per silo, by using only 264 of its SS-18 ICBM's with 8 warheads each. Presuming such an attack came during an alert, most U.S. submarines would be at sea and most bombers could be in the air by the time the missiles arrived. The Soviets could gain little by unleashing more of their missiles on our airbases or submarine bases. A Congressional study estimates that "...both sides would be able to destroy about 40 to 60 percent of the other's silo-based ICBM's." (6) After a Soviet first strike using 264 ICBM's with 2112 warheads and destroying 56 percent of all U.S. ICBM's, we would still have 466 ICBM's left, as shown in Table 1.2a. Now, continuing with the assumptions in the Congressional study, if the U.S. retaliates only against Soviet missiles with the 251 surviving Minuteman III missiles with the 3 warheads each, the forces of both sides would be reduced to those shown in Table 1.2b.

Alternatively, if the U.S. attacked the Soviet ICBM's first, with all 550 Minuteman III missiles, the Congressional study estimates the results as shown in Table 1.3a. A Soviet retaliatory strike (for which there are no figures in the Congressional study) could use 126 of the 172 remaining SS-18's with a total of 1008 warheads against the 504 remaining Minuteman II and Titan II ICBM's. The final force levels would be as shown in Table 1.3b. In either scenario, the Soviet Union is left with approximately 1700 strategic (intercontinental) delivery vehicles and approximately 4000 thermonuclear warheads while the United States is left with approximately 1200 delivery vehicles and approximately 8200 warheads.

 (6) Congressional Budget Office, Retaliatory Issues for the U.S. Strategic Nuclear Forces, pp. 5-19.

Table 1.2a. Soviet and United States Strategic Force Levels
after Soviet Counterforce First Strike

		Delivery Vehicles	Nuclear Warheads

USSR			
	ICBM's	1134	3496
	SLBM's	950	1470
		----	----
	Total	2084	4966
US			
	ICBM's	466	952
	SLBM's	656	5440
	Bombers	340	2560
		----	----
	Total	1462	8952

Table 1.2b. Soviet and United States Strategic Force Levels
after United States Retaliatory Second Strike

		Delivery Vehicles	Nuclear Warheads
=====			

USSR			
	ICBM's	800	2466
	SLBM's	950	1470
		----	----
	Total	1750	3936
US			
	ICBM's	215	215
	SLBM's	656	5440
	Bombers	340	2560
		----	----
	Total	1211	8215

Table 1.3a. Soviet and United States Strategic Force Levels
after United States Counterforce First Strike

		Delivery Vehicles	Nuclear Warheads

USSR			
	ICBM's	791	3652
	SLBM's	950	1470
		----	----
	Total	1741	5112
US			
	ICBM's	504	504
	SLBM's	656	5440
	Bombers	340	2560
		----	----
	Total	1500	8504

Table 1.3b. Soviet and United States Strategic Force Levels
after Soviet Retaliatory Second Strike

		Delivery Vehicles	Nuclear Warheads
=====			

USSR			
	ICBM's	665	2644
	SLBM's	950	1470
		----	----
	Total	1615	4114
US			
	ICBM's	222	222
	SLBM's	656	5440
	Bombers	340	2560
		----	----
	Total	1218	8222

Militarily important targets, beyond ICBM's, include oil refineries, steel mills, automobile manufacturing plants, airfields, shipyards and ports, rail yards, power plants, and high-technology research and manufacturing facilities. Because these facilities are not hardened targets like missile silos, one or two warheads for each target will be sufficient. Whether or not Lancaster would be included in such a list of militarily important centers is debatable, but unimportant, because this almost complete destruction of the U.S. military and industrial capacity could easily be accomplished with only 1000 to 1500 nuclear warheads, leaving 2500 to 3000 for use against cities, including Lancaster.

Because oil refineries, steel mills, shipyards, airfields, etc. are generally located around major cities (especially in the Soviet Union), any reluctance to kill massive numbers of civilians (collateral damage) will have disappeared by this stage in any nuclear war scenario. Remembering that American pilots in bombing sorties over North Vietnam were regularly told not to come home with any bombs and that they therefore bombed churches, villages, or anything else that they could see from the air, it seems likely that whatever destructive capacity either side had remaining would be instinctively and vengefully used to obliterate the other as completely as possible. This is where Lancaster and other smaller population centers would most likely enter the drama.

Suppose that the remaining 2500 to 3000 warheads were to be used on the major population centers. For simplicity of calculation, ignore the fact that many cities will already have been destroyed (collaterally) because of their industrial capacity, and allot them additional warheads solely on the basis of population at the rather generous rate of one warhead per 500,000 persons. New York City would receive 33, Los Angeles 18, Philadelphia 10, Pittsburgh 9, Washington 6, Baltimore 3. Continuing in this fashion through all 545 urban areas in the United States with populations greater than 25,000, bombs would be allotted to the Pennsylvania cities of (in order of population) Scranton, Allentown, Harrisburg, Reading, Erie, York, Lancaster, Johnstown, Easton, Altoona, Williamsport, Sharon, New Castle, Lebanon, State College, Greensburg, Pottsville, West Chester, Titusville, Pottstown, Butler, Hazelton, Washington, Uniontown, Hanover, Latrobe, and Carlisle. These 46 warheads delivered to Pennsylvania would be in addition to those already used on the military and industrial facilities. Much of Pennsylvania (and much of the rest of the nation) will literally be in ashes. Still, this massive destruction of cities throughout the United States has required only 481 of the 2500 to 3000 available Soviet warheads.

Suppose that the ratio of warheads per person is increased so there is one warhead per 200,000 persons. Philadelphia will then receive 23 (even though a single one megaton bomb would be sufficient to kill or injure 2.7 million of the 4.6 million inhabitants of the greater

Philadelphia area).(7) Even with this ratio, 700 warheads are enough to destroy all cities greater than 25,000 several times over. What is to be done with the remaining 1800 to 2300 Soviet warheads? Perhaps the question at the beginning of this chapter should not have been "Is there a bomb for Lancaster?" but "Are there bombs for New Holland, Ephrata, Lititz, Manheim, Elizabethtown, and Columbia?" The problem of "leftover" bombs is even greater for the U.S. In all the scenarios depicted in Tables 1.1 to 1.3b, the U.S. always ends up with a larger total of "leftover" warheads than the Soviets. We have plenty of "extra" bombs for thousands of small Soviet towns.

These assumptions of kill ratios, warheads per target, and the number of targets can be changed, but the end result is always the same. The overkill capacity of both sides is so horrendous that no matter what assumptions one makes, there are still enough warheads and delivery vehicles on both sides to incinerate all cities the size of Lancaster (and much smaller ones, too) many times over.(8) Given that the present strategic policies and technological advancements are leading ever closer to the brink of nuclear war and that a nuclear war, once started, is unlikely to be closely controlled or limited, Lancaster is likely to be directly involved in just such a war.

(7)United States Arms Control and Disarmament Agency, U.S. Urban Population Vulnerability, Washington, D.C., August 1979, pp. 67,98.

(8)One of the objections to SALT II was that it would impose limitations on the U.S. development and deployment of additional thermonuclear weapons. That limitation was 2250 delivery vehicles with approximately 11,000 to 12,000 warheads, somewhat in excess of the present levels shown in Table 1.1.

CHAPTER 2

ASSUMPTIONS IN DESCRIBING LANCASTER'S ATTACK

UNCERTAINTIES

The effects of a nuclear attack on a particular geographic area are influenced by many different factors.(1) Damage estimates vary widely depending on those factors. Although it is impossible to foretell the precise destruction resulting from a nuclear blast, ranges of damage can be established once certain assumptions are made. Factors determining the results of a nuclear attack include the following.

1. Target. The attack might strike strategic forces, military bases, industrial complexes, population centers or a combination of these, with the intent of destroying retaliatory forces or weakening industrial production. Some population and industry would also be destroyed in say, an attack aimed specifically against military targets.
2. Size. The magnitude of destruction will be determined by variations in the number and sizes of warheads, locations of the detonations, whether air or surface blasts are employed, and the duration of the attack. Even nearby attacks or drifting fallout from distant explosions could seriously harm an area not under direct attack.
3. Weather. Climatic conditions during and shortly after the attack are uncertainties over which the attacker has little control except for the season of the year. Wind patterns, precipitation, visibility and dryness of vegetation have considerable influence on the amount of damage inflicted by a nuclear blast.

 (1) Two key sources have been consulted extensively in preparing the technical sections of this study. The Effects Of Nuclear War was released by the U.S. Congressional Office of Technological Assessment (OTA) in 1979 and is distributed by the U.S. Government Printing Office in Washington D.C. A standard reference on nuclear weapons is The Effects of Nuclear Weapons, 3rd edition, by Samuel Glasstone and Philip Dolan, published in 1977 by the U.S. Department of Defense and The U.S. Department of Energy. Although specific quotes from these two references are identified, their influence pervades the bulk of our technical discussions.

4. Shelter. Preparation and protection are uncertainties which influence the magnitude of human destruction. Sufficient warning before an attack could allow officials to move high-risk populations to safer areas. Many other factors such as degree of panic, availability of information, time of day, access to shelters, population location and extent of evacuation will have a significant bearing on the number of deaths and injuries.
5. Post-attack Conditions. Long-term effects are nearly impossible to predict. Shortages of medical care or of food and water supplies, inadequate housing, spread of disease, and other consequences from an attack create situations whose single or multiple effects cannot be precisely determined. The speed of economic recovery, political stability, epidemics, climatic alterations and the morale of survivors are even harder to predict, but may be the more determinative factors in the final results. Attaching numbers to long-term, post-attack effects is extremely difficult and will not be attempted in this report.

ASSUMPTIONS

Although it is difficult to estimate accurately the effects of a nuclear attack because they fluctuate with variations in weather, time of day, wind, bomb size, shelter and relocation, it is possible to specify the nature and extent of damage left by a hypothetical attack after the variable parameters are set. Changes in the postulated conditions would of course alter the calculated effects of the attack. In this section we identify our assumptions and comment on how variations in these assumptions might modify the anticipated effects.

Ground Zero

Penn Square in downtown Lancaster was selected as ground zero, the point on the ground directly above or below the center of the explosion. Since a strike on Lancaster is only likely in the context of a wide-scale attack on industrial and population centers, the center of the city is the logical target. Our estimates of damage assume that the warhead explodes in the air directly over Penn Square. Obviously in any nuclear attack some of the missiles would miss their targets. However, a missile straying from the Penn Square target by 1200 to 1500 feet would make a negligible impact on our calculations.

The Larger Context

It is unlikely that a city like Lancaster would be attacked in isolation, except by error. A medium-sized population center such as Lancaster County would most likely be included in a larger scenario that focuses on military and industrial targets in the Eastern U.S., or in one that involves a full-scale national attack. Consequently, we assume that other population and industrial centers are also under attack at about the same time as Lancaster. While the bulk of this study describes the immediate effects of a bomb burst over the city of Lancaster, we will also discuss the effects of fallout on Lancaster County from a larger regional attack.

Type of Burst

A nuclear bomb can be exploded at ground level or in the air over a target. A surface blast unleashes severe damage close to ground zero, while the explosive effects of an air burst spread out over a larger area and are less intense at ground zero. Because their explosive power is concentrated on a smaller area, surface blasts are used to destroy "hard" targets such as missile silos, nuclear reactors, and military installations with special protection. In contrast, the air burst is used on industrial and population centers because the destructive swath spreads over a much wider area.

Surface and air bursts are also different in the amount of radioactive fallout they produce. A surface blast is considered a "dirty" blast because the explosion at ground level sucks debris high into the air, infuses it with radioactivity and spreads it over a wide area onto which it continues to "fallout" for many days. In contrast to a surface blast, an air burst is a relatively "clean" explosion because its height from the ground prevents rubble from being sucked up into the atmosphere. There is immediate nuclear radiation from an airburst, but the amount of fallout in the hours following the explosion is quite small. Both air and surface blasts send small amounts of radioactive material into the high layers of the atmosphere. This material slowly falls back to earth over many years as "delayed fallout."

Attacks on large industrial centers today would probably use a "package" of both surface and air bursts. Such a combination delivers the worst blast destruction and the most radioactive fallout to a target area. Because there are few "hard" targets like missile silos or protected military installations in the Lancaster area, a surface blast seems unlikely. Although the nuclear reactors at Peach Bottom and TMI might be potential "hard" targets, an air burst is more likely for Lancaster as an industrial and population center because this would maximize destruction. Lancaster County is in the awkward position of possibly receiving a "clean" airburst overhead which produces the worst damage to buildings and the most deaths, and at the same time receiving fallout from "dirty" ground blasts from the Harrisburg area or nearby nuclear reactors.

Height of Burst

The heat generated by a nuclear (or non-nuclear) explosion drives air away from the site of the explosion in a supersonic shock wave. This blast wave accounts for approximately one-half of the energy released in a nuclear explosion. The blast creates a sudden change in air pressure which strikes buildings and large structures and is followed by high winds which injure people by blowing them into (or out of) buildings and throwing debris upon them. Because blast effects diminish with distance, the height of an air burst directly influences the amount of damage. In general, as the burst height increases, the blast damage spreads out over a larger area, but the intensity of the blast near ground zero diminishes. An air burst at 6,000 feet maximizes the geographical area that receives blast pressures of at least 20 pounds per square inch (psi), a pressure sufficient to level reinforced concrete buildings, while an air burst at 10,000 feet maximizes the area that receives at least 5 psi, a pressure sufficient to destroy residences and lightly constructed commercial buildings.

Because most of the areas surrounding Lancaster City are residential, the largest number of fatalities would result from a 10,000 foot explosion. We have chosen a blast height of 6,000 feet for our calculations in this study both to provide a more conservative estimate of fatalities and to provide easier comparison with studies of similar effects on other cities in which 6,000 feet is a typically assumed blast height.

Weapon Size

Strategic weapons are those designed to attack an enemy from long distances and include intercontinental ballistic missiles, submarine missiles and heavy bombers. These delivery vehicles carry warheads ranging in size from 40 kilotons to 25 megatons of TNT. A kiloton is equivalent to 1,000 tons of TNT while a one megaton weapon carries the explosive potential of 1,000,000 (1 million) tons of TNT. The bomb dropped on Hiroshima in 1945 was equivalent to approximately 15 kilotons (15,000 tons) of TNT. Thus, the smallest strategic weapons today are at least twice as large as the Hiroshima bomb. Typical warheads are on the order of 1 to 5 megatons. A one megaton weapon is approximately 70 times more powerful than the Hiroshima bomb.

Our Lancaster scenario uses a one megaton bomb for three reasons:

1. This is the typical weapon size of other scenarios which allows comparison.
2. A larger weapon would probably not be "wasted" on Lancaster since one megaton can sufficiently paralyze the area.

3. Describing the effects of a one megaton bomb provides a helpful grasp of the potential power in the world arsenal today, since megatons are the basic currency of strategic exchange.

Time

The time of day and the season influence the location of people at the moment a bomb explodes. Casualties increase with a daytime attack, since people tend to be concentrated in downtown schools and offices. In the summer, more people are likely to be outdoors and unprotected. In order to utilize the 1980 census information, this study assumes that people are at home at the moment of attack. There is never a time when 100 percent of the population is at home, but since people are more often at home than not, it seems reasonable to use the "at home" assumption. Furthermore we assume that an equal number of people move in and out of a given area at any moment. In brief, random equalization of population movement was assumed so the 1980 U.S. Census data could be used to estimate casualties.

An attack in January would decrease damage to agricultural crops and increase the human fatalities due to inadequate protection from the cold. A summer attack would have the opposite effect. An early evening in spring, when most people had returned home from work and school, was chosen as the time for the explosion. Daylight conditions make it easier to find shelter and cope with the disaster. The estimated casualties would be much higher in a midday attack with people concentrated in downtown areas.

Weather

Varying climatic conditions, e.g., visibility, moisture and wind constrain or amplify the effects of a nuclear explosion. Excessive moisture lowers fire damage and increases the likelihood of radioactive particles washing out of the sky and creating "hot spots." Active winds at the time of the blast could increase the number and spread of fires. Our calculations assume a 12 mile visibility as well as dry conditions at the time of the early evening attack.

Warning

An unknown in estimating the effects of nuclear war is the amount of surprise involved in an attack. Shelters of any sort help to abate some of the damage, at least for persons living in outlying areas. Shelters, however, in downtown Lancaster would be worthless. If the attack resulted from an international crisis that escalated over several days, and if it were expected, sizeable numbers of people might voluntarily evacuate to designated shelters in rural areas.

If the attack came as a surprise, the warning time at best would be 30 minutes for intercontinental ballistic missiles and 5 to 15 minutes for submarine launched missiles. Under such conditions, few people would find a shelter because the location of public shelters is not well known and civil defense drills are something of the past.

As we noted earlier, it is doubtful that the Soviets would launch a surprise first strike on cities the size of Lancaster. It seems more realistic to see an attack on Lancaster coming after an initial counterforce exchange targeted on weapons and military installations. Even in such a scenario, however, the length of warning time could range anywhere from several hours to a week.

Summary

In brief, the following conditions are assumed as the basis for our estimates of the effects of a nuclear attack on Lancaster County.

A one megaton nuclear bomb is exploded 6,000 feet directly above Penn Square in Lancaster in the early evening of a spring day. People are at home and the weather conditions are dry with a visibility of 12 miles. The attack is part of a larger eastern seaboard strike which comes after a short warning of a few hours.

CIVIL DEFENSE

Civil defense could play a major role in limiting the number of deaths resulting from a nuclear attack.(2) There are two basic civil defense strategies: constructing blast and fallout shelters and evacuating populations from high-risk areas to safer ones. Early civil defense efforts in the late 1950's and early 1960's concentrated on identifying and constructing shelter protection in existing buildings or in underground structures such as subways. This approach anticipated a very short warning time before a missile attack.

A major shift in national civil defense policy occurred in September 1978 when Presidential Directive 41 ordered the development of Crisis Relocation Planning (CRP) for larger cities and high-risk areas during an acute crisis. Although the 400 high-risk areas cover only 2 to 3 percent of the U.S. land area, they contain approximately 145 million or about two-thirds of the American population. Crisis Relocation Planning is a seven year project which was implemented by the Secretary of Defense in the 1981 fiscal year.

(2)The discussion of civil defense is based largely on three documents supplied by The Federal Emergency Management Agency: "FY 1982 Civil Defense Program," Revised March 19, 1981. "Questions and Answers On Crisis Relocation Planning," P+P-4, October 1980. "U.S. Crisis Relocation Planning," P+P-7, February 1981.

In brief, CRP is based on the key assumption that a surprise attack is very unlikely and that at least a week of warning time would precede the strike. During this warning week, the 145 million Americans who live in high-risk areas would be "relocated" to safer areas at an average distance of 30 to 50 miles from their homes. The Federal Emergency Management Agency estimates that without any civil defense preparations only 20 percent of the American people would survive a large-scale attack in the mid 1980's. Currently the national survival rate is estimated at 40 percent since CRP is only partially completed. The Federal Emergency Management Agency believes that if CRP is completed by the mid to late 1980's, 80 percent of the U.S. population could survive a wide-scale national attack. Crisis Relocation Planning is especially attractive since it is expected to cost only 2.5 billion dollars over 7 years, which is roughly 30 times cheaper than an extensive blast shelter program which would cost in the neighborhood of 70 billion dollars. The Federal Emergency Management Agency estimates the following relocation rates from high-risk areas during the first three days of a warning period.

Day -----	Percent Relocated -----
First	65
Second	85
Third	95

The next three or four days of the "warning" week would be used to find appropriate housing and devise shelters in the host areas.

A national survey found that approximately 50 percent of Americans would spontaneously evacuate during a warning and another 25 percent would leave their homes if instructed by a presidential order.(3) The roughly 25 percent who probably would not leave is similar to the number who refuse to leave their homes in the face of natural disasters such as floods and hurricanes. During the Three Mile Island incident in 1979, about 40 percent of the people living in a 15 mile radius of the nuclear plant spontaneously evacuated.(4) A full-scale CRP accompanied by a

(3)George Rogers, Presidentially Directed Relocation: Compliance Issues, University of Pittsburgh, Center For Social and Urban Research, May 1980.

(4)Donald B. Kraybill, "Three Mile Island: Local Residents Speak Out," Elizabethtown College, Social Research Center, April 1979. C.B. Flynn, "Three Mile Island Telephone Survey," U.S. Nuclear Regulatory Commission, NUREG/CR-1093, October 1979.

presidential order might result in a higher rate of evacuation. On the other hand, the danger of the TMI incident was clearly identified with a precise geographic location and any movement away from the site was in a safe direction. In the case of a nuclear attack the specific target location will be uncertain and those relocating risk passing through other high-risk areas. These factors complicate relocation efforts in the face of nuclear attack and might increase the percent of persons who refuse to evacuate.

Approximately 3,300 local Crisis Relocation Plans need to be developed before the national plan is complete. As of March 1981, roughly 500 local plans were complete. Lancaster County is preparing a CRP since Lancaster City and the western half of Lancaster County are considered in a high-risk area by the Federal Emergency Management Agency. Lancaster County Emergency Management officials estimate that the Lancaster County plan will be completed sometime in 1983 and the national plan about 3 years later. The Lancaster County plan was accelerated by the development of an emergency evacuation plan for the nuclear reactors at Peach Bottom and Three Mile Island.

In brief, Lancaster County's plan calls for relocating the population living in Lancaster City and in the western half of the County to host areas in Perry County and Eastern Lancaster county. County officials estimate that a successful relocation effort, according to the preliminary plan, would involve moving about 250,000 people. Any crisis relocation effort, no matter how well executed, is not likely to relocate more than 75 percent of its target population.

Confusion will be the order of the day if the warning time is short, because Lancaster's Crisis Relocation Plan is not complete and co-operation with relocation efforts may be low. Confusion will be the order of the day. People will be caught in the throes of deciding if they want to leave, even when an attack may never come. In light of these factors, we think it is fair to expect that 85 percent of the people will still be here. Thus, while a short warning time is likely, it is also very likely that most people will not leave. Because relocation is such an important variable, we shall estimate casualties for a variety of conditions ranging from a surprise attack to a warning time that allows massive relocation of many Lancaster County citizens. The physical damage to buildings and landmarks will be the same regardless of the amount of warning time.

Although the major thrust of U.S. civil defense policy is Crisis Relocation, the study produced by the Office of Technological Assessment raises serious questions about the viability of CRR.

This is a staggering logistics problem. Unless people are assigned to specific relocation areas, many areas could be overwhelmed with evacuees,

causing severe health and safety problems. Unless private transportation is strictly controlled, monumental traffic jams could result. Unless adequate public transportation is provided, some people would be stranded in blast areas. Unless necessary supplies are at relocation areas, people might rebel against authority. Unless medical care is distributed among relocation areas, health problems would multiply.

Once evacuated, people must be sheltered. They might be assigned to existing public shelters or to private homes with basements suitable for shelter. If materials are available and time permits, new shelters could be built. Evacuees require ... life support functions [food, water and other supplies] ... providing these in sufficient quantity would be difficult. Evacuation entails many unknowns. The time available for evacuation is unknown, but extremely critical. People should be evacuated to areas that will receive little fallout, yet fallout deposition areas cannot be accurately predicted in advance. Crisis relocation could increase the perceived threat of nuclear war and thus might destabilize a crisis.

Whether people would obey an evacuation order depends on many factors, especially public perception of a deteriorating international crisis. If an evacuation were ordered and people were willing to comply with it, would time allow compliance? If the attack came while the evacuation is underway, more people might die than if evacuation had not been attempted. Sufficiency of warning depends on circumstances; a U.S. president might order an evacuation only if the Soviets had started one. In this case, the United States might have less evacuation time than the Soviets. The abundance of transportation in the United States could in theory permit faster evacuation, but panic, traffic jams, and inadequate planning could nullify this advantage. Disorder and panic, should they occur, would impede evacuation.(5)

The success of the Crisis Relocation Plan is based on two fundamental but questionable assumptions: that there will be a "warning time" of one to two weeks, and that the massive evacuation will actually work in the moment of crisis.

(5)The Office of Technological Assessment, The Effects of Nuclear War, p. 51-52.

Although a viable CRP will surely save millions of lives if we are fortunate enough to have at least a "week of grace," it will not protect buildings or landscape from massive damage. The twenty to thirty percent of the people (30 million) in high-risk areas who stay behind will most likely be killed or injured. The homes, properties and countryside in the high-risk areas will probably be devastated. Even if a functional CRP were able to relocate 80 percent or 116 million of those living in the high-risk areas, there will be no homes, jobs or historical sites awaiting their return after the attack. Millions of relocated citizens would literally have to "start life over again" in new areas of the country after spending weeks in fallout shelters at their "host" area. Furthermore, while relocation provides protection against a nuclear blast, it does not provide shielding from radioactive fallout which can drift anywhere. So while a CRP might save millions of lives it is foolish to clutch it as a false security blanket and hope that it will alleviate massive human and physical destruction in the face of a full-scale nuclear attack.

LIMITATIONS OF ESTIMATES

Estimates of the damage and casualties caused by a nuclear blast are somewhat presumptuous due to all the uncertainties. There is considerable information available on the effects of a single weapon from Hiroshima and Nagasaki and from testing, but we know little about the combined consequences that might follow the explosion of several or many large bombs. Although the estimates for a particular scenario may be different from an actual attack, they do at least provide a feel for the destructive power of a nuclear weapon. In general terms, the effects of a nuclear explosion can be summarized as follows.

Prompt Effects

- 1) blast
- 2) thermal radiation
- 3) nuclear radiation
- 4) electromagnetic pulse

Intermediate Effects

- 1) mass fires and firestorms
- 2) radioactive fallout

Long-term Effects

- 1) economic and social changes
- 2) psychological effects
- 3) political disruption
- 4) biological and genetic alteration
- 5) climatic changes

Estimates of the effects near the top of the list are usually more accurate than for those near the bottom. Calculations for the long-term effects are virtually meaningless, but as the Office of Technological Assessment reminds us, "the effects of nuclear war that cannot be calculated are at least as important as those for which calculations are attempted."(6)

(6)The Office of Technological Assessment, The Effects of Nuclear War, p. 3.



Mushroom cloud over Nagasaki created by a 22 kiloton bomb, 46 times smaller than a one megaton device.
credit: U.S. Air Force Photo

CHAPTER 3

THE PHYSICAL EFFECTS

The effects of a nuclear explosion can be described in various ways. In this chapter we begin with a very brief overview of a nuclear explosion and then describe an air burst over Lancaster second by second. Then the destructive effects of each aspect of a nuclear explosion, blast, thermal and radiation are explored with reference to Lancaster County landmarks. Finally the multiple effects are summarized by four concentric geographic regions surrounding Lancaster City.

A NUCLEAR EXPLOSION IN BRIEF

The amount of energy released and the destructive power of a nuclear weapon depends on three factors:

- 1) size of the weapon,
- 2) type of nuclear process, and
- 3) design of the bomb.

"Yield" is the technical term used to describe the amount of explosive energy that a nuclear weapon can produce. The yield of nuclear weapons is typically measured in tons of TNT. A kiloton is the equivalent of one thousand (1,000) tons of TNT while a megaton is equal to a million (1,000,000) tons of TNT. In other words, a one megaton bomb has the explosive power of 1,000 kilotons of TNT. The largest conventional bomb packs 10 tons of TNT. One million tons of TNT (one megaton) would fill the box cars of a freight train 300 miles long and would take 6 hours to pass at full speed.(1) The Hiroshima and Nagasaki bombs were on the order of 15 to 20 kilotons. The power of nuclear weapons since then has increased dramatically with weapons in today's stockpiles ranging from 40 kilotons to 25 megatons.

There are two basic types of nuclear process, fission and fusion, and the type of process influences the amount of energy and radioactivity released. Fission involves splitting "heavy" atoms (plutonium and uranium isotopes) into smaller ones producing sudden releases of immense energy. The fission process is used in commercial

(1) The Boston Study Group, The Price of Defense, New York: New York Times Books, 1979, pp. 63-64.

reactors under special controls to ensure that the energy is released slowly. The earliest nuclear weapons or A-bombs exploded over Japan used a fission process.

In 1952 the Hydrogen or H-bomb was developed which uses a fusion process. In this extremely powerful process, atoms of "light" elements (isotopes of hydrogen) are brought together under very high temperatures. The atoms "fuse" together and release enormous amounts of energy. The sun and stars give off energy in the same fashion. The hydrogen bomb requires a small fission explosion first, to create the heat of several million degrees which is necessary to trigger the fusion reaction. Hydrogen bombs, although typically a hundred times more powerful, release less radioactivity than A-bombs. Most if not all of today's stockpiled weapons use a combination of fission and fusion to maximize both destructive blast and nuclear radiation.

LANCASTER'S FINAL MINUTES

An extremely hot, luminous fireball with temperatures of 27 million degrees F., as hot as the center of the sun, forms in the air 6,000 feet above Penn Square.(2) Because the day is clear, the scorching heat of the fireball burns skin and starts small fires as far as 12 miles away in Manheim, Ephrata, Strasburg and Bird-in-Hand. As far as 50 miles away in Coatesville and Shippensburg the fireball feels much hotter than the noonday sun.

The explosion creates a destructive blast wave that moves away from the fireball at supersonic speeds. About 1.8 seconds after the explosion, the front of the blast wave is roughly half a mile ahead of the fireball as it sinks rapidly toward the ground. At the same time hard nuclear radiation in the form of gamma rays and neutrons strike the ground in Lancaster's downtown area. This deadly radiation, similar to a massive X-ray, penetrates everything directly under the fireball. Concrete walls at least four feet thick are necessary to protect people directly under the explosion from the radiation.

Building structures a mile away from Penn Square are smashed and flattened by the mammoth blast unless they were specially designed to resist such shock. As the primary blast wave of air hits the ground it bounces back and forms a reflected blast wave. About 4.6 seconds after the explosion, the primary and reflected blast waves combine together 1.3 miles from Penn Square to form a single destructive shock wave that is literally a wall of compressed air. The shock wave is similar to a

(2) This brief overview of the explosion by time closely follows Kevin N. Lewis' description of the prompt effects of a one megaton explosion 6,500 feet in the air over New York City. Kevin N. Lewis, "The Prompt and Delayed Effects of Nuclear War," Scientific American, July 1979, vol. 241, pp. 35-47.

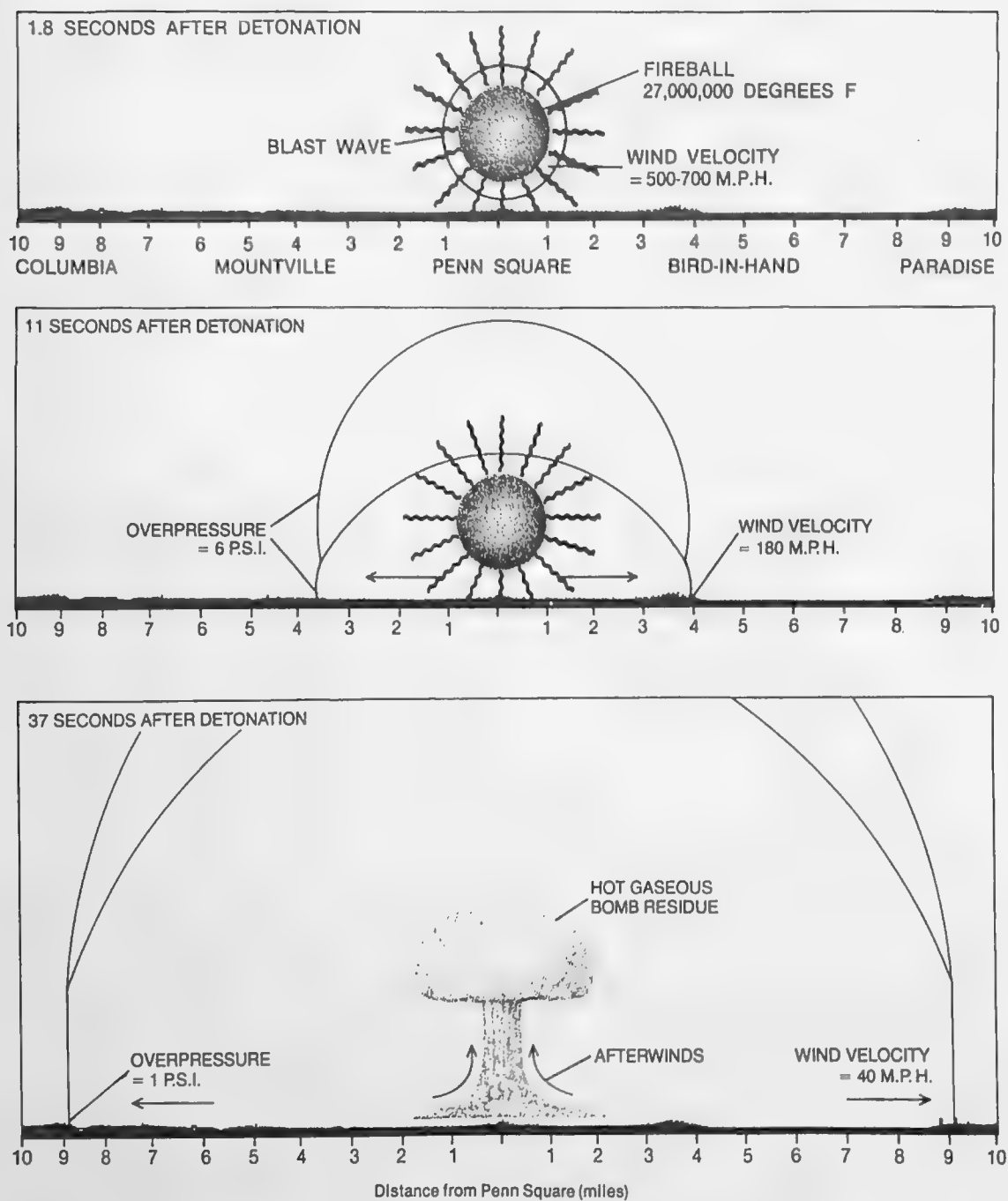


figure 3.1
Time Sequence of Air Burst over Lancaster City

tidal wave which quickly spreads out in all directions from ground zero followed by 500 mph winds analogous to the water currents that follow an ocean wave. The rapid change in atmospheric pressure and the swirling winds smash virtually all buildings and structures in the city.

The major shock wave forms about four and a half seconds after the explosion in a circle charted roughly by the main railroad lines to the north of the square, School Lane Hills to the west, Engleside to the south and Conestoga View to the east. As the shock wave begins around the edge of this circle, the air pressure is 16 psi above the normal atmospheric pressure, and only specially reinforced buildings remain standing. Peak wind velocity following the shock wave along this circle is in the neighborhood of 450 mph. Ten seconds after the blast, as the shock wave moves out across the countryside, the fireball begins rising up above the city and stretches one mile wide.

Citizens living about three miles out in areas like Quaker Hills, Eastland Hills, Rohrerstown, New Danville, Highland Acres, Eden Heights, Bloomingdale and Millersville have 11 seconds to seek whatever shelter they can find before the shock wave hits. At this distance the overpressure will decrease to 6 psi, still sufficient to reduce homes to rubble, and the winds will decline to a mere 180 mph.

Those living 9 to 10 miles away from Penn Square in a rough circle bounded by Columbia, Salunga, Paradise, Akron and Lititz have about 37 seconds to duck for safety before the shock wave arrives. Light damage to window frames and doors, and moderate damage to plaster might reach as far as Blue Ball and Rheems (15 miles out) while glass could be broken as far as 30 miles away from Penn Square.

By 37 seconds the intense burst of heat is gone but gamma rays still bombard the ground in the immediate area around Penn Square. The fireball, no longer flaming but still very hot, begins rising rapidly and pulls air inward and upward in a motion that creates strong air currents called afterwinds. These swirling winds suck dirt and debris from the ground and form the well known mushroom cloud. About two minutes after the burst, the fireball begins cooling at a height of 7 miles and expands in a radioactive cloud filled with vaporized particles. The mushroom cloud reaches a maximum height of 14 miles within ten minutes. In the absence of snow or rain, the radioactive particles are gently dispersed by the wind so that very little fallout drops on Lancaster County.

In less than two minutes Lancaster City and much of the surrounding countryside has been obliterated. A mushroom cloud floats above the smoking desolation. The heart of the Garden Spot has vanished. A few miles out the injured begin to suffer and in the outer edges of the county the dazed survivors shake their heads in disbelief.

FIVE EFFECTS OF A NUCLEAR BLAST

The energy from a nuclear explosion is released in five different ways as portrayed in Figure 3.2.

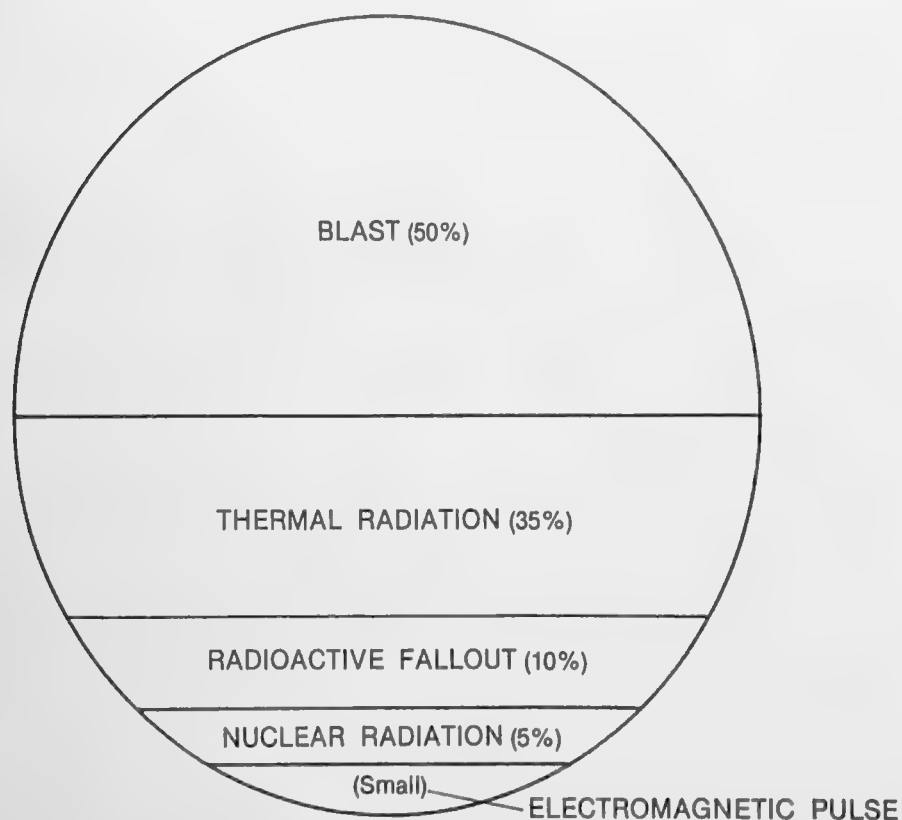


figure 3.2.
Energy Distribution of a Nuclear Blast

About half of the energy is released in the form of a powerful blast, thousands of times stronger than a conventional explosion. Most of the material damage associated with a nuclear explosion is caused by rapid air pressure changes and high winds as these effects spread over a wide area. Approximately 35 percent of the bomb's energy is released as thermal radiation in the form of heat and light. Very little energy (5 percent) is released in the form of immediate nuclear radiation which is

confined to a small area close to the explosion.(3) About ten percent of the energy from the blast is transformed into radioactive particles which later become fallout, and a small amount of the energy is released as an electromagnetic pulse. A description of the types of energy released and their effects is summarized in Table 3.1. Each of these effects in the Lancaster County scenario will be described separately.

Table 3.1 Energy Distribution and Effects of a Nuclear Blast

	Energy	Effects	Damage
Blast	50 %	Explosive Shock High Winds	Buildings Collapse Flying Debris
Thermal	35 %	Light and Heat	Burns and Fires
Radiation	5 %	Gamma Rays, Neutrons	Deaths and Sickness
Fallout	10 %	Radioactive Particles	Contamination
EMP	small	Magnetic Fields	Electrical Systems

SOURCE: Glasstone and Dolan, The Effects of Nuclear Weapons, pp. 6-8.

(3) A conventional nuclear bomb releases 5 percent of its total energy as nuclear radiation. In contrast, the neutron bomb, properly called an Enhanced Radiation Weapon, releases from 30 to 50 percent of its energy as prompt nuclear radiation. The lethal thrust of 8,000 rads of radiation from a conventional one kiloton fission bomb reaches out about 375 meters while a neutron bomb more than doubles the lethal range to 850 meters. While the proportion of radiation released by a neutron bomb is 6 to 10 times greater than a fission bomb, the blast and thermal damage is greatly reduced. Fred M. Kaplan summarizes the difference, "... a one-kiloton enhanced radiation warhead could potentially kill about twice as many tank men as a 10-kiloton fission weapon, but the blast damage would be only about a fifth as large." Fred M. Kaplan, "Enhanced Radiation Weapons," Scientific American, May 1978, vol. 238, p. 6.

Effect I: Blast

The explosive blast creates a powerful shock wave or wall of compressed air similar to a tidal wave which spreads out from the explosion at supersonic speeds. Very strong winds over 500-700 mph near the center of the blast follow the shock wave out. The strength of the blast effects are usually measured in terms of pounds of air pressure per square inch (psi) above or "over" the normal atmospheric pressure of 14.7 pounds per square inch at sea level. Many structures will suffer some damage when the overpressure exceeds one half pound per square inch. The overpressure near the center of an explosion is in the neighborhood of 200 psi and rapidly diminishes as the shock wave moves away from ground zero.

The sudden increase in pressure is followed by a quick drop in air pressure and then finally by a resumption of normal air pressure. These sudden changes are analogous to a giant shaking motion that suddenly pushes buildings in and then yanks them back. This mammoth shaking motion accompanied by high speed swirling winds turns all sorts of objects, e.g., window glass, building fragments, cars, lawn mowers, tricycles, and bottles into flying instruments of death. The report issued by the Office of Technological Assessment describes the blast effects this way:

The blast drives air away from the site of the explosion, producing sudden changes in air pressure (called static overpressure) that can crush objects, and high winds (called dynamic pressure) that can move them suddenly or knock them down. In general, large buildings are destroyed by the overpressure, while people and objects such as trees and utility poles are destroyed by the wind.

For example, consider the effects of a 1-megaton air burst on things 4 miles away. The overpressure will be in excess of 5 pounds per square inch (psi), which will exert a force of more than 180 tons on the wall of a typical two-story house. At the same place, there would be a wind of 160 mph; while 5 psi is not enough to crush a man, a wind of 180 mph would create fatal collisions between people and nearby objects...

For the most part, blast kills people by indirect means rather than by direct pressure. While a human body can withstand up to 30 psi of simple overpressure, the winds associated with as little as 2 to 3 psi could be expected to blow people out of typical modern office buildings. Most blast deaths result from the collapse of occupied

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buildings, from people being blown into objects or from buildings or smaller objects being blown onto or into people. Clearly, then, it is impossible to calculate with any precision how many people would be killed by a given blast - the effects would vary from building to building.(4)

Overpressure regions encircling ground zero can be established, and fairly reasonable projections of material and structural damage can be made for these areas. The blast effects of a one megaton air burst 6,000 feet over Lancaster are summarized in Table 3.2.

As noted in Table 3.2 all structures within a 2.5 mile radius of Penn Square will be destroyed or severely damaged unless they were specially constructed to withstand such strong blast pressures. Four miles away from the center of town, in places like Mylin's Corner, East Towne Mall, Kenwick Village and Flory's Mill, with 5 psi of overpressure, most residences and lightly constructed commercial buildings would be destroyed by the blast effects alone.

In bomb tests conducted by the U.S. Government in the mid 1950's, a two-story brick house without reinforcement was subjected to 5 psi of overpressure. Glasstone and Dolan describe the results.

The brick-walled house was damaged beyond repair. The side and the back walls failed outward. The front wall failed initially inward...the roof was demolished and blown off, the rear part landing 50 feet behind the house. The first floor had partially collapsed into the basement as a result of fracturing the floor joists at the center of the spans and the load of the second floor which fell upon it. The chimney was broken into several large sections.(5)

Brick and frame houses 6.5 miles out near the Lancaster Airport, Smoketown, Refton and Mountville would suffer moderate damage from 2 psi of overpressure but they could probably still be used. The blast effects in these areas would crack wall frames, demolish roofs and twist interior partitions. Strong winds of at least 80 mph would topple about 30 percent of the trees in communities like Landisville 6 to 7 miles from downtown as well as do moderate damage to commercial buildings. As far away as 10 miles in Intercourse, New Holland, Akron, Manheim and Columbia the overpressure would cause some damage to frame buildings and

(4)The Office of Technological Assessment, The Effects of Nuclear War, pp. 16-18.

(5)Glasstone and Dolan, The Effects of Nuclear Weapons, pp. 184.

Table 3.2. Blast Effects of a One Megaton Explosion 6,000 ft.
Over Lancaster

Distance from Penn Square (miles)	Over- Pressure (psi)	Wind (mph)	Typical blast effects
1.7	20	470	Reinforced concrete structures are leveled.
2.5	12	330	Severe damage to all except specially designed structures.
2.7	10	290	Most factories and commercial buildings are collapsed. Small wood-frame and brick residences are destroyed and distributed as debris.
4	5	160	Lightly constructed commercial buildings are destroyed; heavier construction is severely damaged.
5.5	3	95	Walls of typical steel- frame buildings are blown away; severe damage to residences. Winds sufficient to kill people in the open.
6.5	2	70	Moderate damage to commercial type structures. Repairable damage to residences.
10.5	1	35	Light damage to structures; people endangered by flying glass and debris.

SOURCES: The Office of Technological Assessment, The Effects of Nuclear War, p. 18, Table 3.

Glasstone and Dolan, The Effects of Nuclear Weapons, pp. 80-114, 154-219.



Wood-frame house before a nuclear explosion, Nevada Test Site. credit: U.S. Department of Defense.



Wood-frame house after a nuclear explosion (5 psi peak overpressure). credit: U.S. Department of Defense.

Residences four miles away from Penn Square near Willow Valley Square, East Towne Mall, Neffsville, Rohrerstown and Millersville would experience overpressures of 5 psi.



Unreinforced brick house before a nuclear explosion, Nevada Test Site. credit: U.S. Department of Defense.



Unreinforced brick house after a nuclear explosion (5 psi peak overpressure). credit: U.S. Department of Defense.

Residences four miles away from Penn Square near Willow Valley Square, East Towne Mall, Neffsville, Rohrerstown and Millersville would experience overpressures of 5 psi.

would blow out many windows and doors. Interior partitions would be cracked and there would be slight damage to roofs and siding. Most of these damages could easily be repaired. The destruction beyond 10 miles would be minor. However, light damage to window frames, doors and plaster might be found as far as 15 miles out in places like Marietta, Brickerville, Denver and Holtwood. Glass breakage could occur as far as 30 miles away.

Effect II: Thermal Radiation

About 35 percent of the bomb's energy is released as thermal radiation very similar to the heat and light given off by the sun. Temperatures in the center of the fireball are similar to those in the center of the sun and are estimated to be about 27,000,000 degrees F. In contrast, the temperatures of a conventional bomb are only around 9,000 degrees F. Because of the enormous heat, all materials at the center of the explosion are converted into gas which produces tremendous pressures - a million times greater than normal atmospheric pressure.

All of this happens very quickly. About a millisecond after the explosion of a one megaton bomb, even to observers 50 miles away, the fireball appears many times brighter and hotter than the noonday sun. In seven-tenths of a millisecond the fireball stretches 440 feet wide, and in ten seconds it is slightly over a mile wide. Like a hot air balloon, the fireball rises to a height of 4.5 miles within a minute after the explosion. The fireballs of high altitude test bombs have been seen as far as 700 miles away. Like a gigantic heat lamp, the fireball scorches the ground with a two-second flash traveling at the speed of light. This searing flash of heat arrives several seconds before the blast wave, just as lightning precedes thunder. On a clear day, the powerful burst of heat and light could burn the exposed skin of people as far as 12 miles away in places like Intercourse, The Buck, Marrietta, and Sporting Hill.

The enormous temperature near the center of the inferno fries people alive, and melts steel and glass. Concrete surfaces explode within a mile and a half of Penn Square, roughly from the Lancaster County Prison on the eastern side of the city to Buchanan Park on the western edge. The Hiroshima bomb, 70 times smaller than a one megaton device, melted down solid materials with temperatures of 5,400 to 7,200 degrees F. near ground zero. Over half a mile (.6 miles) away the temperatures reached 3,200 degrees F. In Hiroshima human bones were found encased in the center of chunks of molten glass after it had hardened.

Glasstone and Dolan describe the physical effects of the high temperatures as:

... burning of the skin, and scorching, charring, and possibly ignition of combustible organic substances, e.g., wood, fabrics and paper. Thin or porous materials, such as lightweight fabrics, newspaper, dried grass and leaves, and dry rotted wood, may flame when exposed to thermal radiation... Thus fires may be started in buildings and forests and may spread rapidly to considerable distances. In addition, thermal radiation is capable of causing skin burns and eye injuries to exposed persons at distances at which thin fuels are not ignited. Thermal radiation can, in fact, be an important cause of injuries to people from both direct exposure and as the result of fires, even at greater distances than other weapons effects.(6)

The severity of human burns depends heavily on weather conditions at the moment like rain, smog, ice and snow. Since thermal radiation is similar to sunlight, dense objects create shadows behind them where the heat is less intense. Some possible thermal effects of a one megaton air burst over Lancaster are displayed in Table 3.3.

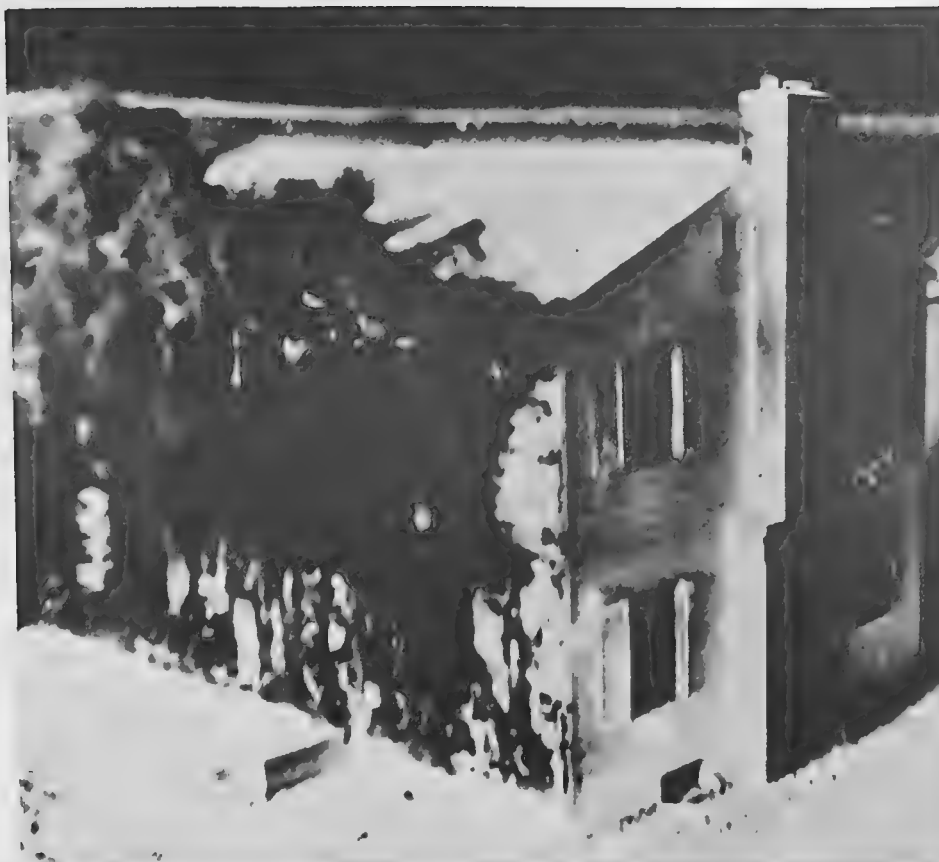
Table 3.3. Thermal Effects of a One Megaton Explosion Over Lancaster

Dist. from Penn Square (miles)	Heat (Cal/cm ²)	Typical Effects
1.5	500	Steel and glass melt, concrete explodes
2.2	100	Aluminum siding evaporates
4.0	50	Wood, plastics, fabrics ignite
5.0	25	Upholstry, canvas, clothing ignite
7.0	10	Newspapers ignite, 3rd degree burns
8.5	5-7	Severe 2nd degree burns
10.5	3	Some 1st degree burns

SOURCE: Glasstone and Dolan, The Effects of Nuclear Weapons, pp. 286-291.

Assumes clear day with 12 mile visibility. Calorie is unit of heat.

(6)Glasstone and Dolan, The Effects of Nuclear Weapons, pp. 277, 283.



Thermal effects on wood-frame house 1 second after test explosion (about 25 cal/cm²). Residences five miles away from Penn Square in Mountville, East Petersburg and Willow Street would likely receive a similar amount of thermal radiation. credit: U.S. Department of Defense.



Shadow of a handle is imprinted by heat rays on a tank 1.3 miles from ground zero in Hiroshima. credit: KIKUCHI Shunkichi and HIROSHIMA-NAGASAKI, A Pictorial Record of the Atomic Destruction.

About 2 miles out from Penn Square in places like the Lancaster County Park, Bausman, Bridgeport and near RCA on Route 23 East, aluminum siding evaporates and lucite windows melt. Even four miles away from downtown in Wilshire Hills, Lampeter and near the Landis Valley Farm Museum, wood, plastics and heavy fabric spontaneously ignite while asphalt surfaces melt. A mile further out, exposed upholstery, canvas, light clothing and household rags are likely to burst into flames, while wood surfaces are scorched in areas like Mountville, East Petersburg and Willow Street. Seven miles from Penn Square in Bird-In-Hand, Conestoga and Kissel Hill, dry newspapers out of doors ignite and neoprene-coated nylon rain wear melts. Ten to twelve miles out in New Holland and Mt. Joy, unprotected persons receive some first degree burns.

After the huge flash, fires begin springing up over a wide area as far as seven miles out from Penn Square. Dry grass, newspapers, weeds and brush may develop starter fires strong enough to ignite a house. Buildings with decayed wooden siding or shingles may ignite directly from the tremendous heat. Such fires could light small barns and sheds and feed larger fires. Some of these early fires might be extinguished by the winds associated with the blast as they arrive after the heat flash. However, new fires will be started indirectly by the blast from broken gas lines, short circuits, overturned stoves, broken power lines, exploding vehicles and burning gas stations.

The amount of fire damage after the initial heat flash depends to a considerable degree on weather conditions at the moment and the amount and density of dry combustible materials such as straw, dry leaves, paper and trash. The damage caused by fire is thus much more difficult to predict than that caused by blast effects.

Fires that begin in a pile of leaves or newspapers outside a house often are not surrounded by enough other combustible fuels to continue burning and expanding. The more serious fires, likely to grow and spread into larger fires, are those that ignite inside a building. Combustible materials such as upholstered furniture, bedding, carpets, papers, and fabrics near a door or window provide kindling for fires in buildings. In a city, especially, the amount of combustible materials required to fuel a fire is more often found inside buildings than outdoors.

The simultaneous ignition of small fires spreading over a wide area can result in two types of mass fires: firestorms and conflagrations. A firestorm is a massive stationary fire created by many small fires merging together. Cool air rushes in from the outside edges and rises rapidly in the center. The heated air forms a rising column in the center similar to the air flow of a gigantic fireplace. As the fire burns hotter and gains momentum, the chimney effect intensifies and sucks more cold air in from the sides causing the fire to burn violently. Although a firestorm is stationary, it consumes most of the buildings within its reach. In contrast to a firestorm, a conflagration

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is a moving fire that is driven by surface winds and continues to burn as long as there is sufficient fuel. A conflagration starts from single or multiple ignition points and spreads out as it is fanned by surface winds.

The temperatures in one of these massive fires can exceed 1,800 degrees F. - high enough to melt glass and metal and burn ordinary fireproof materials. A firestorm in Hiroshima ignited by a 15 kiloton bomb burned for 6 hours and totally destroyed 4.4 square miles of the city or about 2,800 acres near ground zero.

Hamburg, Tokyo and Hiroshima experienced firestorms in World War II; the Great Chicago Fire and the San Francisco Earthquake Fire were conflagrations. A firestorm is likely to kill a high proportion of the people in the area of the fire, through heat and through asphyxiation of those in the shelters. A conflagration spreads slowly enough so that people in its path can escape, though a conflagration caused by a nuclear attack might take a heavy toll of those too injured to walk.(7)

It is quite difficult to predict the potential for firestorms or conflagrations in advance because they depend on a combination of various conditions, e.g., weather, terrain, density and combustibility of buildings as well as the nature of the blast effects. Although it has been argued that in contrast to Hiroshima, American cities are built with more fire resistant materials, Kevin Lewis has noted that American cities are more densely built up and loaded with flammable fuels such as gasoline and heating oil which would feed fires rapidly. More importantly the heat produced by the large weapons in today's arsenal would be much greater.

It is impossible to say whether or not a firestorm or conflagration might start after an attack over Lancaster. A firestorm seems more likely in a larger city where more combustible buildings in the downtown area would remain standing after the blast. A firestorm in Lancaster seems unlikely, but it is possible that a conflagration might develop on the edge of the city where more buildings would be standing. And so while it is certain that thousands of small fires would spring up all over the place, it is impossible to project whether or not they will combine into a massive firestorm or conflagration. The report issued by the Office Of Technological Assessment indicates that the mechanics of fire spread in a heavily damaged and debris strewn area are really not that well known.

(7)The Office of Technological Assessment, The Effects of Nuclear War, pp. 21-22.

Effect III: Nuclear Radiation

In a one megaton air explosion, the blast and heat effects are much more serious and greatly overshadow the damage caused by the initial nuclear radiation. Nuclear radiation in the form of gamma rays and neutrons strikes the area near ground zero like a massive X-ray in the first minute of the explosion. According to Glasstone and Dolan,

The initial nuclear radiation consists mainly of gamma rays, which are electromagnetic radiations of high energy originating in atomic nuclei and neutrons. These radiations, especially gamma rays, can travel great distances through air and can penetrate considerable thicknesses of material. Although they can neither be seen or felt by human beings, except at very high intensities which cause a tingling sensation, gamma rays and neutrons can produce harmful effects even at a distance from their source.(8)

A lethal dose of radiation is generally considered to be about 450 rems, and directly under a 6,000 foot blast the dosage might reach 10,000 rems. Although deadly, the prompt radiation given off by a one megaton explosion will not reach out nearly as far as the blast and heat effects. However, directly under a 6,000 foot air burst a wall of concrete four feet thick would be needed to protect humans from the deadly rays.

Table 3.4 Prompt Nuclear Radiation From a 6,000 Ft. Air Burst

Distance from Penn Square (feet)	Approximate Radiation (rads)	
	Gamma Ray	Neutron
0	10,000	1,000
5,000	1,000	100
7,000	100	30
10,000	30	small

SOURCE: Glasstone and Dolan, The Effects of Nuclear Weapons, p. 324-349.

Figures are approximate since dosage varies with moisture and shielding, etc.

(8)Glasstone and Dolan, The Effects of Nuclear Weapons, p. 8.

Because gamma rays are scattered in the air they arrive at their target from all directions. Nevertheless, a wall, embankment, or hill will provide partial protection. Glasstone and Dolan point out that if some shelter is found within a second of seeing the explosive flash it might make the difference between life and death.

As shown in Table 3.4 the radiation is lethally dangerous in the 1 mile range, but after that its intensity drops off sharply so that for all practical purposes the danger from the immediate radiation is limited to a range of 2 miles from Penn Square. Compared to the radiation given off by a nuclear reactor accident, the "late" or residual radioactivity given off by bomb products on the ground is relatively short lived. Approximately 7 hours after the explosion the radioactivity will have decreased to about one-tenth of its original strength. About 2 days later the "hot" activity will have decreased to 1 percent of its initial value. The human damage caused by the radiation will be discussed with medical injuries in a later chapter. There is still considerable uncertainty and controversy surrounding the nature and effects of the prompt radiation produced by a nuclear bomb.(9)

Effect IV: Fallout

During a nuclear blast, particles of soil, debris and water are sucked up into the fireball and mixed with radioactive substances. As the violent explosion subsides these "hot" particles fall back to earth. The fallout gradually returns to the earth's surface over a period of days and ranges in size from fine sand to chunks the size of a marble. "Early" fallout consisting of the larger pieces usually falls within the first 24 hours near ground zero. Wind and precipitation are key factors in shaping the pattern of fallout dispersal. Some "delayed" fallout may stay aloft for months and be blown hundreds of miles away.

The amount of fallout from a blast ranges from severe to negligible depending on the weather, weapon size, and height of detonation. In general terms an air burst such as this one over Lancaster is considered "clean" since it produces very little fallout. A surface or "dirty" blast sucks up a great deal of soil and debris which later returns as radioactive fallout. In describing the fallout from an air burst such as the one over Lancaster, Glasstone and Dolan say,

Many of the particles are so small that they fall extremely slowly under the influence of gravity, but they can diffuse downward and be deposited by atmospheric turbulence. The deposition

(9)Some revisions in the type and effect of radiation produced by the Hiroshima Bomb were recently proposed in Science, May 22, 1981, Vol 212, pp.900-903, and June 19, 1981, Vol 212, pp. 1364-1365.

takes place over such long periods of time that the particles will have become widely distributed and their concentration thereby reduced. At the same time, the radioactivity will have decreased as a result of natural decay. Consequently, in the absence of precipitation, i.e., rain or snow, the deposition of early fallout from an air burst will generally not be significant.(10)

Fallout from the "clean" air burst over Lancaster City should be very small if not negligible altogether. Fallout from "dirty" surface blasts in nearby states or cities poses a more serious threat for Lancaster, and this threat will be discussed in a later chapter.

Effect V(Electromagnetic Pulse)

A fifth effect produced by a nuclear explosion is an electromagnetic pulse commonly referred to as EMP. The EMP effect was identified in 1962 when the U.S. exploded a 1.4 megaton bomb 248 miles in the air over the Pacific Ocean. In Hawaii, 800 miles away, burglar alarms rang and power line circuits were broken. As described in the Office of Technological Assessment's report, EMP is an electromagnetic wave similar to radio waves but with two important differences.

First, it creates much higher electric field strengths. Whereas a radio signal might produce a thousandth of a volt or less in a receiving antenna, an EMP pulse might produce thousands of volts.
Secondly, it is a single pulse of energy that disappears completely in a small fraction of a second. In this sense, it is rather similar to the electrical signal from lightning, but the rise in voltage is typically a hundred times faster. This means that most equipment designed to protect electrical facilities from lightning works too slowly to be effective against EMP.(11)

EMP poses no direct threat to humans but can knock out electronic and electrical systems. Electrical systems connected by long power lines or antennas are particularly vulnerable. EMP can produce physical damage such as burning out transistors as well as operational disruptions e.g., causing power grids to shut themselves down.

Nuclear explosions at least 19 miles above the earth's surface create very strong EMP's with ranges of hundreds and thousands of miles. There is considerable concern among defense analysts that an enemy could

 (10) Glasstone and Dolan, The Effects of Nuclear Weapons, p. 409.

(11) The Office of Technological Assessment, The Effects of Nuclear War, p. 22.

destroy the U.S. military's command, control and communications system by simply exploding a nuclear bomb at a high altitude over the U.S.(12) An air burst at a relatively low altitude like the one described over Lancaster would produce less EMP than a surface blast. The precise effects of this high energy pulse are impossible to estimate but would most likely cause disruption and destruction of electronic and electrical systems throughout Lancaster County and perhaps nearby areas.

BLAST DAMAGE SUMMARY BY REGION

Descriptions of nuclear blast damage typically follow concentric overpressure regions around ground zero. Estimates of damage in these rings are based on expected overpressures caused by the shock wave. Although the regional boundaries provide useful markers of estimated destruction, they are somewhat arbitrary since the overpressure declines gradually as the distance from ground zero increases. The use of such regions, however, provides a convenient and easily understood way to summarize the combined effects of thermal, radiation and blast effects even though they are constructed on the basis of the blast effects alone, namely psi overpressure. The map in Figure 3.3 and the data in Table 3.5 provide a helpful overview of the four concentric regions that surround Lancaster City.

Table 3.5. Damage Regions Around Lancaster City

Region	Pressure (psi)	Dist. from Penn Square (miles)	Area (sq. miles)	Acres	Damage
I	12	2.5	20	12,800	total
II	5	4.0	30	19,200	severe
III	2	6.5	80	51,200	moderate
IV	1	10.5	210	134,400	light

(12)This issue is discussed by William J. Broad in "Nuclear Pulse(I): Awakening to the Chaos Factor," in Science, May 1981, Vol 212, pp. 1009-1012.



figure 3.3.
 Damage Regions in Lancaster County

Region I (2.5 miles from Penn Square)

Region I is a 5 mile diameter circle that encompasses the city of Lancaster as well as portions of nearby residential areas. It touches Media Heights to the south and to the east crosses Route 30 in the area of Tennyson Drive about three-quarters of a mile east of Bridgeport. On the northern side of the city, the circle runs approximately one-half mile north of Route 283, includes Eden Manor, Grandview Heights and reaches the southern edge of Beverly Estates. The western boundary of Region I passes between Long's Park and Park City. The Barrcrest and School Lane Hills developments are within the circle, as well as the eastern section of Wheatland Hills.

Region I at the heart of the blast receives devastating damage from the shock waves, wind, heat, fire and immediate nuclear radiation. In the inner circle of the region, within 1 mile of Penn Square, the overpressures range from 20 to 30 psi and the accompanying winds rage nearly 700 mph. Near the outer boundary of the region, two and a half miles from downtown, the overpressure declines to 12 psi and the winds slack off to about 300 mph. Virtually all of the structures in this region from Park City on the west to Tennyson Drive east of Bridgeport are demolished beyond repair. The only buildings standing are some reinforced concrete structures on the outer fringe of the region such as parts of Park City. Although the reinforced shells are still standing, they are gutted and damaged beyond repair. Since most multi-story, reinforced concrete buildings are located in downtown Lancaster, it is doubtful that even their shells would be standing. At best the three hospitals, Lancaster General, Lancaster Osteopathic, and St. Joseph's are ragged skeletons poking up through heaps of rubble. Virtually all the homes in this region are demolished and uninhabitable. Even steel frame industrial buildings do not survive the blast.

The enormous shock wave and raging winds flatten this 20 square mile area from Lyndon in the south to Beverly Estates north of Route 283. Here and there a few sturdy building shells jut through gigantic heaps of debris, but they are irreparably damaged. The only structures with a chance of survival are some reinforced highway bridges such as those on Route 283 that span the northern arteries of Route 501 and the Fruitville Pike. The collapse of most buildings and swirling 500 mph winds pile junk and debris high throughout the city making transportation impossible.

Practically all (98 percent) of the people within this region are killed instantly or die shortly after the blast. Although some persons are killed by the sudden and intense overpressure, most die as they are crushed by buildings or hit by flying missiles of bricks, glass and furniture. Persons downtown who survive the powerful blast are fried by heat, killed by nuclear radiation or trapped under the rubble. Only those who found a bomb shelter or are protected by four feet of concrete can survive the penetrating radiation in the downtown area. Many in bomb shelters are trapped and suffocate.



Damage in Hiroshima from a 15 Kiloton bomb 70 times smaller than a one megaton bomb.
credit: U.S. Air Force.



Atomic bomb damage in Hiroshima. credit: U.S. Air Force

Shortly before the blast, thermal radiation scorches everything and fatally burns anyone near a window or outdoors who is not sheltered from the blistering heat of the fireball. The blazing heat spontaneously ignites fires throughout Region I. The falling debris smothers some of the fires, but others begin spreading as they are fanned by the blast winds. Firestorms are not likely in this region since there are not enough standing structures to feed a mass fire.

The explosion levels nearly 13,000 acres including Lancaster City. The sweeping devastation shatters the imagination and is impossible to grasp. The industrial giants, RCA and Armstrong's Lancaster plant, are feeble skeletons jutting up through gigantic rubble piles. In addition to the total destruction of most homes and businesses, McCaskey High School, Franklin and Marshall College and all the elementary schools are gone, as are the offices and stores that make up downtown Lancaster today. Moreover, the historical sites, the Ellicott House, Wheatland, Rockford, The Fulton Theatre and many others are obliterated forever. Lancaster County's Emergency Management Agency located in the Courthouse on South Duke Street is also gone, helpless to coordinate relief and emergency aid throughout the county.

In short, life as we now know it in the center of the Pennsylvania Dutch Country ends. In two minutes a nuclear blast has vaporized the heart of the world's Garden Spot leaving it a blazing inferno and a morbid wasteland. Even hearty survivors would find the task of rebuilding the city difficult, if not impossible.

Region II (2.5 to 4.0 miles from Penn Square)

The second region is a band about one and a half miles wide that circles around Lancaster beyond Region I. The outside perimeter of Region II crosses over Route 272 South near Mylin's Corner. Toward the east, Highland Acres and Eastland Hills are in the region as it extends out to the State Police Barracks near East Towne Mall. On the northern side of the city, Eden Heights, Northbrook Hills and Bloomingdale are situated within the region. The upper boundary intersects with Route 501 just south of Neffsville. The band stretches west then to Flory's Mill along Route 283 and includes Rohrerstown and Manor Ridge as well as the eastern half of Millersville borough.

The overpressure in Region II goes from a high of 12 psi on the inner edges to 5 psi near the outer fringe. Wind speeds range from a high of 275 mph down to roughly 160 mph in the outer areas of the region. Brick and frame houses without special reinforcement in the eastern section of Millersville and near East Towne Mall are damaged beyond repair. Other homes of typical construction in the Rohrerstown, Eden and New Danville areas suffer a similar fate. Industrial plants constructed of light steel and covered with aluminum siding, such as the Howmet Plant along Route 72 North, experience severe and usually irreparable damage. Multi-story office buildings with some

reinforcement in the region, such as the library at Millersville State College, receive moderate damage but can be repaired in most cases. The Landis Valley Farm Museum is severely damaged and its wooden buildings are blazing.

High winds in this region, ranging from 270 to 160 mph, topple most trees and strip any remaining ones of their leaves and branches. The blast damage alone destroys most automobiles while heavier commercial trucks and machinery survive in the outer areas like Rohrerstown. Very few vehicles of any sort, however, are protected enough to remain useful. Some of the telephone poles and many of the power lines lie twisted among the debris. Even in this region where some of the more sturdy structures might remain in repairable shape, the cost of rehabilitating such buildings with the added cost of clearing away the wreckage would not be economically feasible in comparison with building anew in another location.(13)

The Office of Technological Assessment estimates that 10 percent of all buildings in this region would sustain a serious fire. People in this region without shelter receive third degree burns from the heat of the fireball as well as flame burns from fires. In addition to the skin and flame burns there is spontaneous ignition of clothing. While the danger from fire and its destruction increases as we move into Region II, the danger from immediate nuclear radiation is gone since gamma rays generally do not travel this far.

The usual estimate of fatalities for this region is 50 percent, with another 40 percent injured and 10 percent of the population safe from harm. Buildings collapsing on people and flying missiles of debris cause the largest number of deaths. But in contrast to Region I, a larger proportion of the deaths here result from flame and burn injuries. In general, as the distance from Penn Square increases, the proportion of deaths due to blast effects declines and fatalities resulting from burns and fires increase.

In summary then, the 19,000 acres in Region II have fared better than those in Region I. Some buildings still stand, others can be repaired, there is little radiation damage, and 10 percent of the people are safe. However, in this band stretching out to Millersville, East Towne Mall and Mylin's Corner, most individual residences have only their foundations and basements remaining. Industrial buildings on the inner fringe of this region, such as those in the High Industrial Park, are demolished, while structures on the outer edge such as the Freight Truck Depot near Flory's Mill are repairable. The depth of debris that

(13) Arthur Katz, The Social and Economic Consequences of Nuclear Attacks on the United States. Published by the Committee on Banking, Housing and Urban Affairs, U.S. Senate, U.S. Government Printing Office, 1979, p. 29.

clutters roads and landscape varies by the size and density of buildings. The devastation and ruin of Region I and Region II combined covers about 50 square miles as it extends out from Penn Square four miles in all directions. For all practical purposes these two regions are desolate and uninhabitable.

Region III (4.0 to 6.5 miles from Penn Square)

Region III covers 80 square miles in a two and a half mile wide band that goes south on Route 272 to Herrville and crosses Route 222 near the Pequea Creek north of Refton. Toward the east, the region includes Bird-In-Hand and intersects with Route 23 between Leacock and Leola. The Lancaster Municipal Airport and the town of East Petersburg are included in the region. The western boundary passes between the Kellogg Plant and Landisville and then cuts through the center of Mountville.

Even 6 miles out from Penn Square, with the overpressure declining to 2 psi, the damage from fire and blast is substantial. Windows are blown out of large buildings, and window frames and partitions are twisted. The contents on the second floor of buildings with light walled construction are blown out onto the ground. Load bearing walls are severely cracked and some small residential buildings are totally destroyed or severely damaged.

Although many cars and trucks are operable, the roads are impassable because 30 percent of the trees are blown down. Some airplanes and hangars at the Lancaster Airport are destroyed. Wooden structures like the covered bridges that span the Pequea Creek in Lime Valley and others in this region are seriously if not completely destroyed or burned.

Dry leaves, grass, household rags and newspapers ignite spontaneously even this far from the blast. About 4 out of 5 people exposed to the blast in this region receive third degree burns. This is the area with the most severe fire hazard since fires are more likely to spread in places where many buildings are still standing close together.

In this third ring of destruction, covering about 51,000 acres, only 5 percent of the people die. Nearly half are injured and about half remain safe. There is no immediate radiation damage this far out; only destruction from the blast and heat. Life in a primitive fashion will go on in this region. The majority of buildings can be repaired and used again. Here the dead are buried by the survivors.

Region IV (6.5 to 10.5 miles from Penn Square)

The final band of destruction is roughly four miles wide with its outside border stretching about 10 miles out from Penn Square. The southern edge cuts across Route 272 about a half mile north of Truce. Strasburg is inside the circle, as is Leaman Place on Route 30 East. New Holland, Ephrata and Mount Joy are all approximately one mile beyond the outer edge while Akron, Lititz and Manheim are inside. The perimeter goes through downtown Columbia, crosses the Susquehanna River in the Washington Boro area, returns again to Lancaster County at Pequea and then continues east through Mt. Nebo and Rawlinsville.

In this region there are few deaths and the damage is light. Within this region some windows and doors are blown out and interior partitions are cracked. Moderate plaster damage could extend out as far as 15 miles to New Holland and Maytown. There is slight damage in this region to wood and frame buildings as well as to roofs and siding. Kindling fires may ignite half-way into this region, and about 18 percent of the people with exposed skin near the outer boundaries will receive first degree burns. Some flashblindness and retinal burns will also occur in this region. About 25 percent of the people in Region IV will be injured, but virtually none will die within the first 30 days.



Flash burns on skin corresponding to the dark portions of kimono worn at the time of explosion.
credit: U.S. Department of Defense.

CHAPTER 4

THE HUMAN EFFECTS

MEDICAL INJURIES

Information regarding the extent and type of injuries to be expected in a nuclear attack comes primarily from the medical evidence surrounding the nuclear explosions at Hiroshima and Nagasaki in 1945. The casualties produced by a nuclear bomb are much higher than those caused by a conventional explosion for four reasons:

1. The amount of explosive energy released is much greater.
2. The air pressure changes last longer, increasing their damage.
3. The amount of thermal energy (heat) is much higher.
4. There are injuries from the nuclear radiation.

The single and combined effects of blast, heat and radiation cause deaths and injuries. The sudden changes in air pressure and the swirling winds produce both direct and indirect injuries. Direct blast injuries to the body result from the rapid changes in air pressure, while the indirect blast injuries are caused by flying glass and other missiles which puncture the body. People are also tossed and blown through the air by the high-speed winds, thus adding to the indirect blast injuries. Flash burns from the direct heat of the fireball and flame burns from fires are the primary types of burn injuries. Finally, radiation damage can result from immediate nuclear radiation at the time of the explosion, from early fallout (within the first 24 hours), and from long-term fallout which may continue for weeks and months after an explosion. In addition to the injuries caused by the blast, heat and radiation, their combined effects also produce casualties.

The proportion of injuries associated with these three effects of a nuclear explosion vary with weather, terrain, protection, shelter, and the type of explosion. Among the survivors of the Japanese bombings the types of injury were distributed as shown in Table 4.1.

Table 4.1 Distribution of Injuries in Hiroshima and Nagasaki

Blast	70 %
Burns	65 %
Radiation	30 %

SOURCE: Glasstone and Dolan, The Effects of Nuclear Weapons, p. 546.

Because many individuals suffered more than one type of injury the total adds up to more than 100 percent.

Direct Blast Injuries

The rapid change in air pressure caused by a blast wave subjects the human body to sudden and severe compression which can produce internal bleeding and rupture the abdominal and chest walls. The lungs and great vessels are particularly likely to rupture and hemorrhage from a severe blast, and air may enter the blood stream and travel to the heart or brain causing death. Ear drums could be ruptured as far as four miles away from Penn Square. In Japan, individuals with significant direct blast injuries did not survive. Many survivors without serious blast injury reported temporary loss of consciousness because the sudden compression disrupted blood circulation to the brain, or because of concussions from flying missiles.

Indirect Blast Injuries

These injuries result from flying missiles of debris striking the body at high speeds and from the body itself being blown into hard objects. For example, a single pane of glass could shatter into hundreds of sharp fragments traveling at the speed of sound. Table 4.2 shows some of the displacement effects caused by the blast.

As noted in Table 4.2, persons two and one-half miles from Penn Square in an area like Media Heights might be thrown or blown nearly 300 feet. Injuries will range from small abrasions and fractures to serious lacerations and fatal damage to vital organs. The severity of the damage largely depends on the size and speed of the objects that collide with the body.

Table 4.2. Displacement Effects of a One Megaton Air Burst
6,000 ft. over Lancaster

Dist. from Penn Square (miles)	Blast Overpres. (psi)	Winds (mph)	Effects
0.8	35	750	Fatalities from severe ear and lung damage
2.8	7	220	Erect persons thrown 280 feet
4.0	5	160	Erect persons thrown 22 feet at 14 mph
6.7	2	70	Some broken bones and wrenched muscles.

SOURCE: The Pittsburgh Study Group, The Effects of Nuclear War on the Pittsburgh Area, unpublished manuscript, 1962, p. 13.

Burn Injuries

A rough estimate from the bombing of the two Japanese cities revealed that 50 percent of the fatalities resulted from severe burns of one sort or another. In Hiroshima, which was subjected to a small 15 kiloton bomb, burn injuries were fatal to nearly all unprotected persons within a mile of ground zero. It is estimated that 13,000 to 20,000 persons (roughly 20 to 30 percent of the fatalities) died from direct (flash) burns. Approximately two-thirds of those who died in the first day were badly burned. Under the best of circumstances, infection is a serious problem for burn victims. At Hiroshima, burn victims continued to die over the next several weeks because of inadequate medical treatment. Because a nuclear blast would destroy medical facilities and supplies and thoroughly disrupt all means for their delivery to those in need, widespread infection would be a continuing cause of death following any nuclear attack.

Flash Burns

Flash burns, caused by the direct heat from the fireball, occur in the same manner as sunburns. Such burns are likely on the face, neck and hands since these are often the most exposed parts of the body. Flash burns can occur under lightweight clothing of a dark color. Persons outdoors or standing near windows or open doors are the most vulnerable to flash burns.



Hiroshima burn victims at Army quarantine station. credit: ONUKA Masayoshi and
HIROSHIMA-NAGASAKI, A Pictorial Record of the Atomic Destruction.

Heat injuries range from first degree to third degree burns depending on the victim's distance from ground zero. A third degree burn destroys the skin and leaves permanent scars. The nerve endings are burned, the eyeballs melt in their sockets, the hair is singed to the roots, the skin is charred black and may peel off with minimal pressure. A second degree burn results in painful blistering of the skin. If the victim is properly supported with antibiotics and fluids, a second degree burn will heal without scarring, and hair growth will resume. A first degree burn is equivalent to a sun burn and will heal without medical attention. Second or third degree burns over 20 percent of the body are considered major and require special medical care in a hospital. Third degree burns over 25 percent of the body or second degree burns over 30 percent of the body often produce shock and require complicated medical treatment.

Flame Burns

Flame burns from burning clothing or other fires are an indirect effect of the fireball's scorching heat. These burns are like the ones received from touching a hot stove or an open flame. In contrast to flash burns, flame burns often cover the entire body since they are not caused by direct exposure to the fireball. Among the survivors in Japan, flame burns made up less than 5 percent of the total burn injuries. Most of those who suffered flame burns didn't survive because they were trapped and burned alive in burning buildings.

Eye Injuries

Looking at a nuclear blast can produce flashblindness and retinal burns. Flashblindness is a temporary loss of sight ranging from a few seconds to several minutes and often occurs even if the eyes are not focused on the fireball. Although sight usually returns without permanent damage, the flashblindness can trigger other accidents if drivers or pilots lose visual control for a few minutes. Retinal burns are permanent injuries caused by overheating the retinal tissue when the image of the fireball is focused in the eye. The natural tendency to glance directly at the fireball in the first second increases the chance of retinal burns. Such burns usually do not cause complete blindness but rather leave permanent blind spots in the area of vision. Retinal burns can occur at great distances from the fireball. A bomb of one megaton or greater in size, exploded 25 miles above the ground, may produce retinal burns as far away as the horizon on a clear night.

All persons outdoors in a town like Willow Street 5 miles away would receive third degree burns. Even 10 miles away in Columbia and Manheim, exposed persons would have an 18 percent chance of receiving a first degree burn. Retinal burns could occur as far as 30 miles away in places such as Coatesville, Reading, Lebanon and Harrisburg. On a

cloudy day these distances would be cut in half while at night they would be doubled. A summary of the burn and eye injuries by distance from Penn Square is shown in Table 4.3.

Table 4.3 Burn and Eye Injuries By Distance From Penn Square

Dist. From Penn Square (miles)	Flash Burns	Eye Injuries
5	100% of exposed persons receive 3rd degree burns	Flashblindness Retinal Burns
7	82% of exposed persons receive 2nd degree burns	Flashblindness Retinal Burns
10	18% of exposed persons receive 1st degree burns	Flashblindness Retinal Burns
30	No skin burns	Retinal Burns

SOURCE: Glasstone and Dolan, The Effects of Nuclear Weapons, pp. 291, 565, 573. This Table assumes a 6,000 Foot, one megaton airburst with 12 mile visibility.

Nuclear Radiation Injuries

Although nuclear radiation is a unique effect of a nuclear explosion, it is not likely to be a major cause of deaths. In the Lancaster scenario, most persons within lethal range of the nuclear radiation would be killed by the blast and fire effects. However, for Lancaster County's surviving population, the more serious threat from nuclear radiation would come in the form of early and delayed fallout from other attack sites such as Harrisburg and Pittsburgh. The extent of injury from radiation is determined by the amount and length of exposure. Some of the medical effects are seen immediately while others are delayed for years.

Immediate Radiation-Injuries

The amount of radiation that a body receives is usually measured in rems (Roentgen-equivalent-in-man) and indicates the extent of biological damage. Exposures under 100 rems generally do not result in any immediately observable effects; however, victims may experience long term damage 10 to 15 years later in the form of leukemia or other cancers. The lethal threshold for exposure is generally considered to be 450 rems, a dosage at which 50 percent of those exposed would die within a short time. A dose of 600 rems would kill 90 percent of those exposed. These lethal rates assume a vigorous and healthy population. In the case of the very young or old or among the sick, the fatality rate would be higher.

Individuals exposed to more than 100 rems will experience loss of appetite, nausea, vomiting, headache, dizziness and fatigue during the first day following exposure. Individuals exposed to more than 400 rems will experience internal hemorrhaging, diarrhea, loss of hair and even seizures or prostration prior to death.⁽¹⁾ With proper medical attention and hospitalization, individuals receiving between 200 and 450 rems could expect to recover; however, the radiation damage seriously lowers their resistance to other diseases and infections from burns and wounds. The initial symptoms are often followed by a latent period of several days to two weeks when the victim feels well. Later, though, the initial symptoms return and the victim develops fever and internal bleeding. These effects result from the direct radiation from the bomb as well as from the early fallout arriving in the first 24 hours. In addition, if radioactive particles come into contact with the skin, a form of radiation injury known as "beta burn" occurs on the exposed skin.

Delayed Radiation Injuries

Some of the biological consequences of nuclear explosions do not emerge until years later. The known, long-term injuries include cataracts, leukemia or other types of cancer, decreased fertility, accelerated aging, early death, retardation of children, and genetic mutations. Cataract formation generally occurs among individuals exposed to more than 200 rems. With exposures over 200 rems, various types of leukemia appear after a latent period of 1 to 2 years. Animal experiments and the Japanese evidence suggest that large doses of radiation increase the frequency of various types of cancer other than leukemia. Other data show that aging, early death from non-specific causes and temporary sterility increase with radiation exposure. A marked increase in miscarriages, stillbirths and infant deaths occurred among pregnant mothers in Japan who received large doses of radiation.

⁽¹⁾Glasstone and Dolan, The Effects of Nuclear Weapons, p. 579.

Among the surviving children, the frequency of mental retardation was also higher. Physician Katherine Kahn summarizes some of the long-term effects of radiation damage in Hiroshima:

Five to ten years after the bombings, an increased incidence of leukemia was noted among children; ten to twenty years after exposure an increased incidence of leukemia in adults in the fourth and fifth decades at the time of the bombings was noted. Fifteen years after the bombings, a marked increase of cancers of the breast, thyroid and lungs was noted, a less but definite increased incidence of lymphoma, multiple myeloma and cancer of the stomach, esophagus, urinary tract and salivary glands has also been reported.(2)

According to Glasstone and Dolan, the long-term genetic mutations might double among members of a population exposed to 50 rems of radiation.(3) The delayed genetic effects, although serious, are not well known or documented because of the lack of experimental data on humans.

Combined Injuries

We have treated the injuries of each effect of the explosion, blast, heat and nuclear radiation, as though they happened separately. In reality, in a disaster of this scope, many individuals would suffer multiple injuries and their combined effect would produce even more casualties than any one of the effects alone. Moreover, any injuries from which a victim would normally recover might also be turned into a fatality by deteriorating post attack conditions such as poor sanitation, lack of shelter and malnutrition.

Among the Hiroshima survivors about 50 percent of those near ground zero received combined injuries. Two general conclusions emerge from the bombings in Japan.

1. Combined blast and heat injuries were responsible for the majority of the deaths within the first 48 hours of the attack.
2. Delayed fatalities and complications were more frequent among burn victims because they had also been exposed to radiation.

(2) Katherine Kahn, Health Effects of Nuclear Power and Nuclear Weapons, Physicans For Social Responsibility, Watertown, Mass. 1980, pp. 9-10.

(3) Glasstone and Dolan, The Effects of Nuclear Weapons, p. 613.

A few examples of combined injuries illustrate the problem. Severe burns, although not fatal, place great stress on the blood cells. If a burn victim also receives a strong but not deadly dose of radiation, he will probably die because the radiation damage thwarts the body's ability to recover. Victims receiving sublethal doses of radiation in addition to lacerations, concussions, fractures and internal injuries may not survive the multiple and combined stresses placed on the body. Any combination of burn, blast, radiation and environmental stress, e.g., cold, malnutrition or excessive fatigue will produce more fatalities than would normally result from one isolated effect.

Indirect Injuries

Beyond the injuries produced directly by the explosion other casualties are likely to be caused indirectly. For example, individuals who are dependent on special drugs such as insulin, cortisone and digitalis may be cut off from new supplies. Kidney patients requiring dialysis treatment will find travel to treatment facilities impossible even if they are still available. Pacemakers necessary for some heart patients are likely to be disrupted or stopped by the intense electromagnetic pulse. The health of other patients who are bedfast at home or dependent on outside care such as visiting nurses, meals-on-wheels or on special oxygen supplies will be seriously jeopardized. These disruptions as well as many other unpredictable ones will indirectly raise the number of injuries and fatalities.

ESTIMATED CASUALTIES

Any attempt to project numbers of casualties involves considerable conjecture due to the variety of contingencies involved. Most estimates of deaths include only the prompt fatalities from the blast and in some cases flame burns. Although many projections of casualties do not include delayed deaths caused by flame burns, firestorms, fallout and combined effects, such fatalities will be considerable for weeks following the attack. For example, in a Boston scenario with a firestorm and considerable fallout, Kevin Lewis estimates that delayed deaths will increase the early toll by an additional 75 percent. The number of delayed fatalities is difficult to predict because it varies greatly with firestorm activity and fallout density which in turn are highly dependent on the weather conditions of the moment.

Estimating casualties is useful for purposes of illustration, but it does nevertheless rest on probabilistic assumptions. Within limits, the accuracy of a specific set of numbers makes little difference when describing a disaster of this magnitude. Although the numbers represent rough approximations, it is helpful to spell out the assumptions on which they rest. While we believe that a surprise attack is unlikely, for purposes of illustration, we will first describe fatalities and injuries under the "everyone at home" assumption. Then using this as a base we will show how fatality rates might fluctuate with various evacuation rates.

Generally speaking, there are two procedures for calculating the prompt fatalities produced by blast effects. The "lethal area" approach assumes that the number of people who survive within the worst damage areas (5 psi or greater) will equal the number killed in the outlying areas. Thus the number of fatalities is the same as the number of people living within the severe damage areas. An alternate procedure, described by the Office of Technological Assessment, presumes a specific percentage of the persons within each damage area to be killed or injured. This method is considered relatively conservative in its estimates of casualties because it is cautious at every step. It assumes, for example, that half of the people whose homes collapse on top of them will nevertheless survive. In this study, we have used the latter, more detailed procedure, together with the death and injury rates determined by OTA (summarized in Table 4.4) to estimate the number of deaths and injuries. For example, based on the assumptions in

Table 4.4. Blast Casualty Rate Assumptions by Region

Region	Dist. From Penn Square (miles)	Dead	Injured	Safe
I	0 to 2.5	98%	2%	0
II	2.5 to 4.0	50%	40%	10%
III	4.0 to 6.5	5%	45%	50%
IV	6.5 to 10	0	25%	75%

SOURCE: The Office of Technological Assessment, The Effects of Nuclear War, p. 19. Fatality estimates are for those who die within 30 days of the attack. Casualty estimates do not include those caused by fire or delayed effects.

Table 4.4, we would expect virtually everyone to be killed within Lancaster's central blast circle from Park City on the west to about a half mile east of Bridgeport.

Our projections are based on 1980 U.S. Census data provided by the Lancaster County Planning Commission. This information included a map of Lancaster County census tracts and an enumeration of the total residents for each census tract. The percentage of expected casualties from Table 4.4 was used to calculate the number of estimated dead and injured for each census tract in the four blast regions around Lancaster City. In cases where a census tract spanned different blast regions, the population of that tract was apportioned to the different blast regions. Based on these calculations estimated casualties were

projected for each of the blast regions and Lancaster County as a whole. These are reported in Table 4.5 and are based on the assumption that no evacuation occurred.

Table 4.5. Prompt Casualties From Blast Effects by Region
Around Lancaster Without Evacuation

Region	Miles From Penn Square	Population	Dead	Injured	Safe
I	0 to 2.5	78,000	76,000	2,000	0
II	2.5 to 4.0	30,000	15,000	12,000	3,000
III	4.0 to 6.5	32,000	2,000	14,000	16,000
IV	6.5 to 10	71,000	0	18,000	53,000
Beyond	+ 10	151,000	0	0	151,000
TOTAL		362,000	93,000	46,000	223,000

Moving out from Penn Square the number of fatalities declines and the number of injured increases. There are few survivors within a 2.5 mile radius of Penn Square. Even four miles away in a circle that touches East Towne Mall, eastern Millersville and Rohrerstown, the blast effects alone leave 91,000 dead, 14,000 injured and only 3,000 unscathed survivors. In the outlying areas of Region III and IV there are few deaths but many injured. In the county as a whole the blast effects alone leave 93,000 dead and 46,000 injured.

In addition to the deaths and injuries due to the blast, there are also prompt fatalities and injuries from flash burns among those who would otherwise have survived the blast. The OTA methodology assumes that all of the blast survivors who are exposed within 4 miles of ground zero will die from flash burns, and half of those exposed in the 4-7 mile range will receive flash burn injuries requiring medical attention. Assuming that 10 percent of the population is outdoors and unprotected on a clear spring evening with a 10 mile visibility, we can expect an additional 1,700 fatalities in Regions I and II and 1,500 injuries in Region III resulting from flash burns due to the direct heat of the fireball. Thus in Lancaster County as a whole these combined effects of blast and heat might produce approximately 94,700 prompt deaths and 47,500 injuries without evacuation.

Our estimate of about 95,000 prompt blast and flash burn victims is similar to two other independent estimates. The "lethal area" approach, where all the residents of the two inner blast regions are considered

fatalities yields a toll of 108,000 deaths. In 1979 the U.S. Arms Control and Disarmament Agency estimated prompt fatalities for 545 urban areas with populations of 25,000 or more. Their study projected 103,000 fatalities for Lancaster from a one megaton air burst. While our estimate is the lowest, all three projections fall within a range of 95,000 to 108,000.

In addition to the prompt casualties, there will be delayed deaths and injuries resulting from firestorms, flame burns from burning buildings, radioactive fallout drifting into the area from other attack sites and combinations of these factors. Estimates of these delayed casualties are quite precarious because they may fluctuate wildly depending on sudden shifts in wind patterns or the development of mass fires. These delayed deaths and injuries might increase the number of casualties anywhere from 5 percent to 75 percent depending on conditions. Using a modest assumption of 10 percent for Lancaster yields an additional 9,500 deaths and 4,800 injuries for a county-wide total of approximately 104,000 deaths and 52,000 injuries from both prompt and delayed effects.

Table 4.6. Summary of Lancaster County Casualty Estimates
Without Evacuation

	Dead	Injured
Blast	93,000	46,000
Flashburn	1,700	1,500
Delayed	9,470	4,750
TOTAL	104,000	52,000
(rounded)		

Because any such estimates are crude at best, it is helpful to consider a range of casualties between some lower limit under the very best of circumstances and an upper limit resulting from a "worst case" scenario. Three scenarios spanning this range will be described briefly. The casualty estimates for each scenario summarized in Table 4.7 were obtained by adjusting the total "at home estimates" of Table 4.6 by the expected evacuation rate. We assumed that there is a direct correlation between the rate of evacuation and the decrease in fatalities.

Best Case

This scenario assumes that the attack comes at the end of a week-long international crisis which allows Emergency Management officials enough time to evacuate the city and surrounding suburbs to host areas in Perry County and Eastern Lancaster County. As noted earlier, the best crisis relocation effort probably would not be able to move more than 75 percent of the population. This scenario arbitrarily assumes that 75 percent of the citizens are relocated, consequently reducing the fatality rate by 75 percent. Moreover, the best conditions are assumed with no mass fires and very little fallout, resulting in only 5 percent delayed fatalities. These all-around good conditions in this best possible case would leave about 25,000 dead.

Modest Case

This modest scenario assumes that there are at least a few hours or at most a day of warning time. Given the short notice, we arbitrarily assume that 15 percent of the people do evacuate thereby reducing the "at home" fatality estimates by 15 percent. In this case the delayed casualties are arbitrarily set at 10 percent due to light fallout and some mass fire activity. This modest scenario which we believe is the most likely, results in the death of about 89,000 persons. We will use this rounded casualty figure resulting from this scenario throughout the rest of this report.

Worst Case

The worst case assumes a surprise daytime attack when more people are working and shopping in the downtown area. Lancaster County Planning Commission officials estimate a net influx of 16,000 people in the city during the daytime hours because of employment alone. If shoppers, tourists, etc. are included in the daytime increase we can expect an additional 20,000 fatalities since virtually everyone in the downtown area will be killed. This scenario also assumes severe fire activity and considerable fallout which might increase the delayed fatalities by 30 percent all of which yields a total of nearly 150,000 deaths.

The ratio of fatalities to injuries varies considerably with conditions. Generally speaking, as the fatalities increase the proportion of injured declines because many of the injured die. For example, in the worst case scenario with a higher than normal population in center city and with mass fires and heavy fallout, fatalities would be very high but the number of injured relatively low since few would survive.

Table 4.7. Lancaster County Casualty Estimates Under
Different Scenarios

Scenario	Evacuation	Dead	Injured	Safe
<hr/>				
"At Home" (base)	0%			
Prompt		95,000	47,000	
Delayed(10%)		9,000	5,000	
		-----	-----	
Total		104,000	52,000	206,000
<hr/>				
Best Case	75%			
Prompt		24,000	12,000	
Delayed(5%)		1,000	1,000	
		-----	-----	
Total		25,000	13,000	324,000
<hr/>				
Modest Case	15%			
Prompt		81,000	40,000	
Delayed(10%)		8,000	4,000	
		-----	-----	
Total		89,000	44,000	229,000
<hr/>				
Worst Case	0%			
Prompt		115,000	27,000*	
Delayed(30%)		35,000	8,000	
		-----	-----	
Total		150,000	35,000	177,000
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*In the worst case, injuries are reduced by 20,000 from the "at home" estimate of 47,000 since the fatalities are increased by this number in the daytime surprise attack.

Regardless of scenario, the number of dead and injured left by a one megaton explosion would create staggering devastation and an enormous demand for medical care. The physical pain, the emotional suffering, the loss of property and obliteration of landmarks would be unprecedented and terrifying. Even under the worst case scenario, roughly 49 percent or about 177,000 Lancaster Countians will survive the blast without death or injury. This will not be the end of the world for these survivors, but they will be starting life over again in a very different world.

MEDICAL CARE

Facilities

Lancaster County's medical facilities would suffer severe damage in a nuclear attack. The three largest hospitals with 1108 beds are all located in the city, and would be destroyed. Columbia Hospital would have some windows and doors blown out as well as cracked walls and light damage to the roof. Ephrata Community Hospital would probably remain intact. If the Ephrata and Columbia Hospitals are still functional, Lancaster County would be left after the attack with 226 hospital beds and 13 constant/intensive care beds for about 44,000 injured residents.

Table 4.8. Lancaster County Hospital Bed Capacity Before and After Attack

	Constant Care*		Total Beds	
	Before	After	Before	After
Lancaster General	34	0	565	0
Lancaster Osteopathic	12	0	222	0
St. Joseph's	16	0	321	0
Ephrata Community	10	10	150	150
Columbia	3	3	76	76
	--	--	----	----
County Total	75	13	1334	226
No. Per 1,000 pop.	0.2	0.05	3.7	0.8

SOURCE: Provided by the Hospitals in July 1981. Assumes a pre-attack county population of 362,000 and a post-attack one of 273,000.

*Includes constant care and intensive care beds.

Hershey Medical Center, which would likely escape damage even if the Harrisburg area were attacked, has 343 beds with 24 designed for critical care. The Hershey facilities, however, would probably be under seige by survivors from the Harrisburg area. The picture of 44,000 injured Lancaster Countians being accommodated in 226 hospital beds illustrates the hopelessness of receiving even basic medical care after the attack. If 25,000 of the injured required hospital care there would be 110 patients for each bed.

Apart from not having enough beds available, the collapse of transportation, communications, power and water supplies would make it virtually impossible for the injured even to find a bed. Any essential ties that the Ephrata or Columbia Hospitals had with Lancaster City in terms of personnel, supplies, power, drugs etc. would be severed. So although these two hospitals might still be standing, the wide-spread demolition around Lancaster would certainly hamper their operation if not make it completely impossible.

Would nurses, physicians, technicians and maintenance employees of the Ephrata and Columbia hospitals who live in other areas of the county travel back to their hospitals even if the roads were passable? Those who lived within the severe damage areas around the city would already be dead.

Most of the 47 emergency ambulances in the county are based outside the city and it is possible that 25 or 30 of these might still be operational after the attack. Even if the roads were passable where would such emergency vehicles take the injured? Would the emergency medical technicians who drive the vehicles be willing to leave their fallout shelters and their families and take unknown risks?

Finally, who would coordinate the emergency recovery effort since the Emergency Management Agency's headquarters in the County Courthouse would already be destroyed?

A disaster of this sort and magnitude would likely leave thousands of severe burn victims in its wake. In order to survive, such persons need immediate and complicated hospital care. The Effects of Nuclear War study reports that a single nuclear weapon can produce as many as 10,000 burn cases. However, the U.S. at best only has facilities to treat 2,000 such cases. The state of Pennsylvania as a whole has facilities for 60 severe burn victims. The Crozier-Chester Medical Center, which is the closest burn facility to Lancaster, has room for 15 burn patients. A physician describes the complicated care required for a 20 year old patient in the burn unit of a Boston hospital who died after 33 days of comprehensive care.

He had been in an automobile accident in which the gasoline tank exploded and had incurred very extensive third degree burns. During his hospitalization he received 281 units of fresh

frozen plasma, 147 units of fresh frozen red blood cells, 37 units of platelets and 36 units of albumin. He underwent six operative procedures, during which wounds involving 85 percent of his body surface were closed with homografts, cadaver allograft and artificial skin.(4)

Multiplying the need for such intensive medical care by the thousands of Lancaster County burn victims provides a picture of the hopelessness of medical care after the attack.

Personnel

Generally speaking, medical personnel such as physicians and nurses tend to be disproportionately located in major urban areas and are less likely to survive an attack than the population at large. A midday attack over Lancaster would likely produce proportionately higher casualties among medical personnel since many would be in offices and hospitals in the city. Within our "modest" scenario which occurs in early evening, many physicians would have returned to their homes in the suburbs or countryside beyond the worst damage areas. Some of course live in the city, others would be performing evening duties at their office or hospital, and others might be attending social functions within the city limits.

For purposes of illustration we arbitrarily assume that only 20 percent of the medical personnel are killed or injured since they are more likely to be at home in the early evening hours. This is less than the 35 percent casualty rate in the general population. Our lower estimate for medical personnel is based on the premise that their homes are more likely to be located outside the city limits. Without knowledge of their residential location, it is impossible to make an accurate prediction of the physician casualty rate. Our estimate of a 20 percent casualty rate among county physicians is quite conservative and depending on conditions of the attack it could be 50 percent or higher.

A before and after estimate of medical personnel numbers is shown in Table 4.9. There are 365 physicians (M.D. and D.O.) listed in the 1980 Physicians Directory of Lancaster City and County. Of these, 124 maintain an office in the county and 149 are in family or general practice. The total number of physicians includes psychiatrists, pathologists, and other specialists, some of whom may have little recent experience treating burn or radiation injuries. A total of 2538 licensed nurses (R.N. and L.P.N.) reside in the county as well as 481 emergency medical technicians.

(4)Howard Hiatt, "The Medical Consequences of Nuclear War," in A Matter of Faith, Washington D.C.: Sojourners, 1981, p. 31.

Table 4.9. Lancaster County Medical Personnel Before and After Attack

	Before	After
Lancaster County Physicians(1)		
General Family Practice	149	119
Surgeons	44	35
Others	172	138
Physician Office Location		
Lancaster City	241	0
Lancaster County	124	124
TOTAL M.D./D.O.	365	292
Physicians Per 1,000 population	1.0	1.1
Lancaster County Nurses(2)		
Licensed LPN	871	697
Licensed RN	1667	1334
Hospital Employed LPN	402	322
Hospital Employed RN	1013	810
Total Licensed LPN/RN	2538	2031
Lancaster County Emergency Technicians (3)		
	481	385

(1)Physician Directory of Lancaster City and County 1980.

(2)Lancaster County Health Profile (1980). H200.236p 6-80, Division of Health Statistics, Pa. Dept. of Health.

(3)Lancaster County Emergency Management Agency, 1981.

Using the 20 percent casualty rate, the attack reduces the number of physicians in the county from 365 to 292. All the city offices of the 241 physicians who maintain one there will be destroyed. Approximately 54 of the family practice physicians have an office within the severe or total damage areas. It is reasonable to expect that approximately 90 to 100 of the family practitioners located in outlying areas will survive the attack and have offices that are still intact. It is also possible that 35 surgeons may escape injury but they would need to share five operating rooms - one in Columbia and four in Ephrata. Although nearly 300 physicians might survive, if things go

well, some of them would not be trained or experienced in treating the type of injuries produced by the bomb and most of them would have extremely limited or no facilities in which to provide treatment.

Apart from these difficulties, there would be wholesale disruption and, in many cases, destruction of communication, transportation, supplies, drugs and support personnel. Medical personnel as well as other public service officials would be caught in the quandry of looking after their own families in makeshift shelters and at the same time responding to the staggering public need. In a few short moments the bomb would create an incredible need for medical treatment while simultaneously obliterating the medical care system. If 44,000 injured patients sought a physician's care, each of the surviving 292 doctors would be faced with about 151 patients. Such a neat picture is not very likely in the immediate aftermath of the attack. In reality, many physicians and patients would not find each other because of their fear of radiation exposure and because roads filled with rubble and demolished vehicles would make travel impossible. Some physicians might face hundreds or even thousands of injured while many other doctors and patients would never find each other. Those fortunate enough to locate each other might have no facilities for treatment and would certainly face rapidly diminishing supplies. Physicians in the outlying areas like Quarryville, Elizabethtown, Ephrata and New Holland would be best able to offer rudimentary care to those who found their way to these clinics and offices.

Medical facilities and personnel are geared for average, not catastrophic demands for medical service. Even in the case of small emergencies like an airplane crash, prompt medical care depends on a stable and intact social system. The massive number of people wanting treatment, the destruction of facilities, personnel, supplies and the rupturing of the social fabric will create incredible and unbelievable medical treatment problems.

Medical Treatment

In such dire circumstances, protection from simple infection will be difficult since antibiotics and vaccines required to control infection will be exhausted quickly.

Many of the people suffering from burn and blast injuries would normally require the service of orthopedic and plastic surgeons. Such specialists will have neither the facilities nor the supplies necessary for their work. Doctors who are able to function will be forced to be extremely selective because of the enormous demands placed on them. Many will need to practice triage - the policy of denying service to those likely to survive without it as well as to those likely to die even with treatment. In this way they are able to concentrate their services on the most salvageable patients. But even triage will be difficult to practice because common diagnostic tools such as X-ray

equipment may not be available. Without such instruments it will be difficult to know who to treat among the hundreds of survivors with fractures, ruptured organs and lacerations. Since most patients will not know their level of radiation exposure and because radiation symptoms, including depression, nausea and listlessness are difficult to distinguish from the effects of physical and emotional stress, it will be extremely difficult to decide who to treat and who to turn away.

The doctor to patient ratio produced by the catastrophe will be additionally burdened by patients with preexisting illnesses which require continuing care and by those who believe that they were exposed to radiation. The intangible nature of the radiation hazard will likely cause dread among the healthy and send many of them searching for a doctor.

Sidel, et al., describe some of the disruptions that physicians might encounter.

These include destruction of transportation, communication and electricity; contamination and depletion of food supplies, destruction of housing and fuel, destruction and pollution of public water supplies and disruption of garbage and sewage disposal as well as other sanitary facilities.(5)

In the face of all of these difficulties, the medical care of the injured will at best be superficial and crude. In addition to physicians and surviving nurses, emergency medical technicians and laymen trained in first aid may be able to provide some relief and temporary care to the injured. These first aid dispensers will face the same severe limitations as physicians, and their first aid will often be effective only if adequate care is provided later.

Many of the fatally injured persons will never see a physician or a nurse for even a pain killer before they die. Many of the injured who under normal circumstances would survive will gradually die from serious infection in the weeks after the attack. Many other less seriously injured persons will need to cope with survival without medical treatment of any sort. Radioactive fallout arriving from other attack sites could halt all medical care for days because everyone including physicians would be afraid to leave their homes or shelters. In the weeks following the attack, as debris in outlying areas is cleaned up, some of the injured may be transported to hospitals in more rural areas that might have survived a direct hit such as Lebanon or Perry County. Since Harrisburg, York and Reading likely received their own share of

(5)Victor W. Sidel, H. Jack Geiger and Bernard Lown, "The Physician's Role in The Postattack Period," New England Journal of Medicine, Vol. 266, No. 22, 1962, p. 1141.

bombs the remaining and more isolated hospitals would be overwhelmed with demands for service.

Public Health

Fresh water and food may be more crucial to life than being surrounded by medical specialists during the first days after the explosion. Normally a person requires from 50 to 150 gallons of water per day for typical activities. Individuals in the heavy damage areas would be fortunate to have even a quart of water.(6) A family trapped in the basement of their home as a temporary fallout shelter might be sitting next to their well, yet have no water because electrical service is cut off.

Epidemics are unlikely in the early period after the attack but they may appear if immunization programs fail. The carriers of epidemic disease may survive radiation injury better than the human population and could give rise to outbreaks of encephalitis, hepatitis, etc. The radiation might produce mutant forms of viruses which could be difficult or impossible to control. Survivors weakened by fatigue, malnutrition and emotional stress might be much more vulnerable to bacterial infection than they would be under normal circumstances. Poor hygiene in shelters and in heavily damaged areas, as well as the breakdown of the medical system would contribute to the epidemic threat.

A special public health problem with this kind of disaster will be disposing of the dead. Corpses in the center of the blast area will not create a disposal problem; many of them would have been literally cremated, leaving only ashes. Morton Sontheimer, a member of the first group of Americans to enter Nagasaki after the bomb, described the corpses near the center of the blast as, "a circle of fine white ash, not thick enough to feel through my boot soles...I had seen many of those spots on my way to point zero...later I learned to distinguish the small irregular oblong spots, many fewer, that had been animals - dogs or cats I guess. Altogether there were thousands of spots."(7)

On the outskirts of Lancaster City and in the surrounding suburbs where damage is severe, prompt disposal of the dead will be crucial. Quick removal is necessary to control rodents, flies, insects and epidemic disease. Some evidence suggests that emotional disorders follow the sight and smell of rotting bodies which also makes the removal necessary. Some areas or perhaps the whole city would need to be fenced in, cordoned off and placed under quarantine. After a hypothetical attack, Boston is described in this way: "The city is lost

 (6)Sidel, et al., "The Physician's Role in the Postattack Period," p. 1142.

(7)"My Turn," Newsweek, June 29, 1981.

and rehabilitation is unthinkable until residual radioactivity has effaced itself. It may be far simpler to build new cities elsewhere and allow the dead to sleep in their memorial."(8) And so the center of any city after a nuclear attack may become a mausoleum.

Conjecture and speculation are the only guides to estimating public health conditions after such an attack. No amount of planning or preparation prior to an attack can improve the effective recovery of the medical system afterwards. If Lancaster were one of many industrial cities involved in a national attack it is not likely that any significant help would arrive from the outside to alleviate our dire medical needs. Certainly nearby counties that had survived the hit would do what they could, but their help and facilities would be miniscule in the face of such unprecedented need mushrooming up in all directions.



Nagasaki victim, August 10, 1945. credit: YAMAHATA Yosuke, and HIROSHIMA-NAGASAKI, A Pictorial Record of the Atomic Destruction.

(8)Sidel, et al., "The Physician's Role in the Postattack Period," p. 1143.

CHAPTER 5

THE DELAYED EFFECTS

In the preceeding sections of this report we have described the immediate effects of a nuclear explosion in Lancaster County. There are also delayed consequences which pose long-term threats to the Garden Spot. Four such effects which we shall address in this chapter are:

1. radioactive fallout arriving from attack sites outside Lancaster County,
2. agricultural damage from injuries to plants and animals,
3. social and psychological disruptions, and
4. long-term genetic and environmental changes.

The last three of these could result from either an attack on Lancaster or attacks on nearby counties or states.

FALLOUT THREAT

As we noted before in Chapter 3, an air burst over Lancaster City would be a "clean" explosion producing virtually no fallout in Lancaster County. There are however two other scenarios in which Lancaster would not be hit directly but would receive considerable fallout:

1. A general strike against both military and industrial centers in the U.S.,
2. A counterforce attack directed primarily at U.S. military targets.

Either of these scenarios would likely produce lethal levels of radioactive fallout in Lancaster County even though no bombs fell directly on the county itself. It is generally estimated that at least half of the bombs in either scenario would be exploded on the ground and it is these "dirty" surface blasts that would spread the deadly fallout across the country. The dispersion pattern of fallout particles after a nuclear attack depends on the weather, especially on wind and precipitation. It is impossible to predict exact levels of fallout for.

specific communities in advance. In the case of a general attack, the Federal Emergency Management Agency notes that, "No area in the U.S. could be sure of not getting fallout, and it is probable that some fallout particles would be deposited on most of the country."(1)

The forecast for Lancaster's fate in a general nuclear attack is much bleaker than this statement suggests. The U.S. Arms Control and Disarmament Agency (ACDA) estimated fallout rates across the U.S. after an enemy strike against U.S. strategic forces, military installations, and industrial centers with the assumption that half of the weapons are exploded on the ground.(2) Given these conditions the ACDA estimates that the entire northeastern U.S., including Lancaster, will be exposed to at least 1000 rems of radioactive fallout. As noted before, a dose of 450 rems is generally considered lethal to about 50 percent of the people exposed. Based on wind patterns and targets, the ACDA also projected general regions in which the radiation levels from fallout would reach 4500 rems. These areas are identified on the map in Figure 5.1.



figure 5.1.
Areas Receiving 4500 rems of Fallout
(Arms Control and Disarmament Agency)

(1) Federal Emergency Management Agency, "U.S. Crisis Relocation Planning", P+P 7, Feb. 1981, p. 3.

(2) U.S. Arms Control and Disarmament Agency, "Effects of Nuclear War," Washington, D.C., 1979, pp. 16-26.

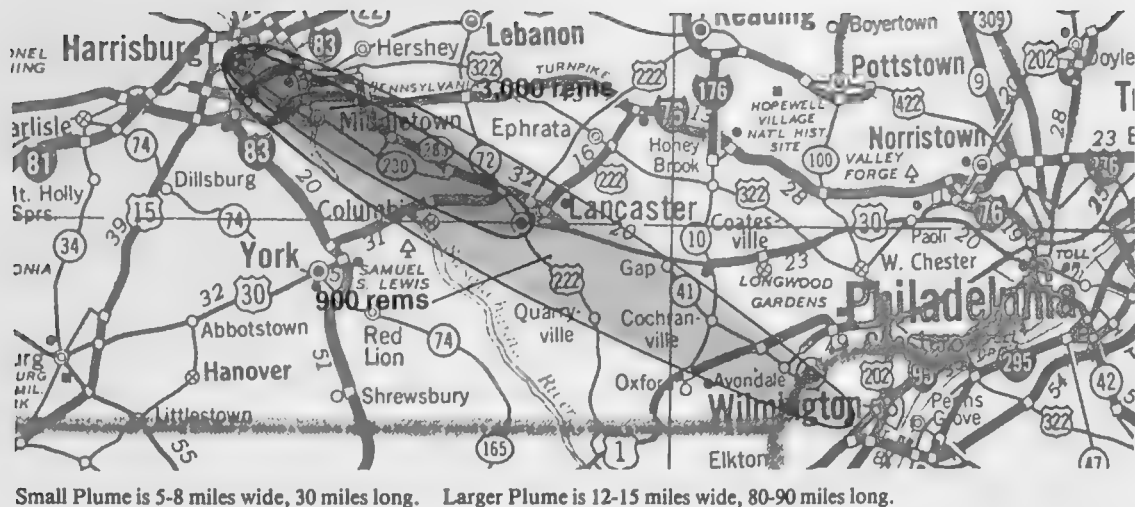
Lancaster County is on the eastern edge of a large radioactive region receiving 4500 rems or more that stretches across Ohio and Pennsylvania. Based on the ACDA calculations we can estimate that in a large scale nuclear exchange, Lancaster County would probably receive fallout from other attack sites ranging from 1000 to 4500 rems, and most likely near the upper end of the range. The arrival time of Lancaster's fallout would depend on wind patterns and distance from the target. Fallout from nearby attack sites such as Harrisburg would probably begin dropping on Lancaster 15-30 minutes after the attack, while fallout from targets 100 to 200 miles away may not arrive for 5 to 10 hours. The Office of Technological Assessment describes the fallout threat for the Boston to Norfolk corridor after a general military and industrial attack.

Almost one-fifth of the U.S. population lives in this small, 150- by 550-mile area. Aside from the threat of destruction from direct attack, these populations are in the path of fallout from attacks on missile silos and many industrial targets in the Pittsburgh, St. Louis, and Duluth triangle. Depending on the winds at [high] altitude, the fallout from the Midwest will begin arriving 12 to 30 hours after the attack.(3)

It is more difficult to estimate ranges of fallout for Lancaster if a nuclear attack is restricted to a counterforce strike on military targets alone. While precise estimates are impossible, it seems certain that Lancaster would receive fallout from a strike restricted to military targets since there are several such targets within 200 miles of Lancaster County. These targets include Frankford Arsenal, the Philadelphia Naval Shipyard, Willow Grove Naval Air Station, Aberdeen Proving Grounds, Ft. Detrick, Ft. Belvoir, Ft. Meade, Ft. Ritchie, Indian Head Naval Ordnance Station, Andrews Air Force Base, Bolling Air Force Base, and White Oak Naval Surface Weapons Center, among others.

For purposes of illustration it is helpful to consider the amount of fallout Lancaster would receive from a surface blast in Harrisburg. It is possible that Harrisburg would be attacked under both the general scenario as well as the military one, since it is a state capital in an industrial area and has potential military targets e.g., New Cumberland, as well. A one megaton surface blast in the Harrisburg area would cause little blast or thermal damage in Lancaster County but would pose a serious fallout threat. Assuming that winds from the Northwest were blowing at a uniform speed of 15 mph, a radioactive plume at the 3000 rem level would protrude east from Harrisburg about 30 miles as portrayed in the map in Figure 5.2. The plume, which might be 5 to 8

(3) The Office of Technological Assessment, The Effects of Nuclear War, p. 96.



Small Plume is 5-8 miles wide, 30 miles long. Larger Plume is 12-15 miles wide, 80-90 miles long.

Figure 5.2

Radioactive Fallout from a One Megaton Surface Blast in Harrisburg with Uniform 15 mph Northwest Winds

miles wide, would nearly touch the western edge of Lancaster City. A broader plume with fallout levels around 900 rems would extend about 80 to 90 miles east of Harrisburg - virtually to Wilmington, Delaware.(4) Although the size and shape of the radioactive plume will vary with weather conditions, typical Northwest winds would most likely dump much fallout on Lancaster County after a Harrisburg attack. Moreover, the combined fallout from several military attack sites in the eastern U.S. virtually guarantees that radioactive fallout would be a threat to Lancaster County even if a nuclear attack could be limited to military targets.

FALLOUT SHELTER

The first 24 hours after the arrival of fallout is generally the most dangerous period of time. In areas where the radiation levels are a serious threat, the fallout will appear as a thin layer of dust consisting of fine grains which look like sand or salt. Special instruments are needed to measure the radiation because the radiation which the particles give off can not be felt, smelled nor seen. As radioactive particles drop from the sky, the levels of radiation in exposed outdoor areas will continue to accumulate. Likewise, the longer a person is directly exposed to radiation, the greater the total accumulated level which is absorbed by the body.

(4) These estimates of fallout patterns are based on the Office of Technological Assessment's projections for a one megaton surface blast on Detroit. The Effects of Nuclear War, pp. 23-24.

The potency of the radiation given off by fallout particles "decays" and drops off sharply after the first 7 hours. For example, radiation levels of 1000 rems the first hour will decline to 100 rems after 7 hours and to 10 rems after 49 hours. Although this appears like a rapid drop in radioactivity, several years may be required until an area is "naturally" decontaminated to peacetime safety standards. It would take 2 to 3 years for an area receiving about 100 rems and nearly 10 years for areas with 3000 rems to return to peacetime "safety" levels.(5)

Protection from radiation is possible and follows a very simple rule: the greater the mass between a person and the source of radiation, the greater the protection. Materials vary a great deal in the amount of protection, or Protection Factor (PF) they provide. For instance, 3.7 inches of steel and 18 inches of earth will reduce gamma radiation by a PF of 10, while it would take 50 inches of wood to get the same results. Hence the saying that "fallout protection is as cheap as dirt." A typical basement without special adaptations would provide a PF of 10, thus reducing the inside level of radiation to one-tenth of that outside. Although staying in the basement would greatly reduce the threat of radiation death, a family in a typical basement for seven days would still receive an accumulated dose of almost 400 rems if the radiation levels outside totaled 4000 roentgens.(6) Such a level would create severe radiation sickness and would be fatal to nearly 50 percent of those exposed. With time and training, unskilled people could increase the safety of their basements by covering exposed windows and walls with several feet of dirt. Beyond the technical problems of estimating radiation levels and preparing adequate protection, people will have to cope with psychological shock, panic and communication difficulties. The Office of Technological Assessment describes some of the problems which will arise in the short time between the news of an attack and the arrival of fallout. This description would certainly portray the dilemma of many Lancaster Countians if they suddenly learned that fallout was coming their way because of a surprise attack on U.S. military targets.

This prearrival period would thus be one of intense activity and intense confusion. How would people react? Training could help, but people trained in how to behave under fallout conditions would fare poorly if they could not get to shelters or if shelters were unstocked. To what extent would people panic, seek other family members, or evacuate spontaneously, and what would be the consequences of such actions?

 (5)The Office of Technological Assessment, The Effects of Nuclear War, p. 23.

(6)The Office of Technological Assessment, The Effects of Nuclear War, p. 51.

Evacuation would probably be a poor choice, since it would be difficult or impossible to predict which would be the safe areas and which the hot spots, and since a car in a traffic jam would offer poor shelter indeed. The decision on whether or not to evacuate, however, is complicated because evacuation is a reasonable response for people who would be at risk from blast from further attacks even though evacuation is a poor strategy for people at risk from fallout alone.

Shelter would in theory be available to a majority of people, although the best available shelter might not be good enough in areas where the fallout proved to be very intense. However, the practical difficulties of fallout sheltering could be very great. The time to seek shelter could be very limited (and people would not know how long they had), and people would want to get their families together first. A shelter must have a sufficient protection factor. Fallout particles must be kept out of the shelter, which requires a ventilation system more complicated than an open window or door, and if anybody enters a shelter after fallout has fallen there must be some means of decontaminating the new arrival. Water is necessary; heat may be necessary depending on the time of year; sanitation is a problem. Finally, people could not tell how long it was necessary to stay in the shelter without rate meters.(7)

After the fallout began dropping and most Lancaster Countians were either in a makeshift shelter or scrambling for one, a seige of a week or perhaps a month of shelter life would begin, depending on the levels of outside radiation. Since few Lancaster Countians have training, preparation, or shelters, this "shelter period" would entail unprecedented confusion and terror. It is difficult to imagine living in a makeshift basement for several weeks under the threatening blanket of radiation dust. Even though fortunate enough to survive a direct attack, Lancaster Countians would likely need to spend some time "underground." The Office of Technological Assessment describes some of the difficulties of such an ordeal.

For several days or weeks, radioactive contamination would be so intense that people in fallout areas would have to stay in shelters or

(7)The Office of Technological Assessment, The Effects of Nuclear War, p. 82.

evacuate. What might be called the "shelter period" begins at each location when fallout starts arriving and ends when people can leave their shelters long enough to do a day's work. The length varies from place to place; many places will receive no fallout, and some hot spots will be hazardous long after surrounding areas are safe. Note, however, that people could go outside for brief periods before an 8-hour day outside a shelter became safe, and could not live in houses with a low protection factor for weeks afterwards. After 2 or 3 months people would ignore the residual radiation, though it would be far higher than is considered "safe" in peacetime.

For the first 10 to 30 days, shelterees would have to remain in shelters almost all the time. Brief excursions outside, for example, to obtain water or food, would substantially reduce the effective protection factor. Life in a shelter would be difficult at best. People would not know if the shelter offered a sufficient PF, or whether further attacks were imminent. The shelter might be dark, as power could be out, and windows would be covered with dirt. Unless the shelter had a good air filtration system, the air would become clammy and smelly, and carbon dioxide concentration would increase. Supplies of food and water might or might not be adequate, depending on what people brought and how many people were in a shelter. Unless the shelter were stocked, medical supplies would probably be inadequate. This would be a severe problem in light of unhealthy conditions in shelters. People who required special medicines would be threatened unless they could obtain an adequate supply. While most people would have radios to receive broadcasts, few would have two-way radios to transmit. While phones might or might not work, it would be difficult to obtain help, as anyone in a contaminated area who left shelter would be in jeopardy from radiation. In particular, medical care would probably be unavailable because of the radiation risk of going to a hospital and the tremendous number of patients seeking help at the few hospitals that remained open.

Radiation sickness would present special problems. Exposures too low to cause acute radiation sickness nevertheless weaken bodily resistance to infection. Resistance would also be

weakened by a deterioration in sanitation, prolonged exposure to heat or cold, lack of medical care, psychological shock, and inadequate food, water, and medicine. Hence shelterees would be especially vulnerable to contagious diseases, ranging from colds and influenza to typhoid fever. There is a trend in the United States away from immunization; as a result, many would contract diseases they otherwise would not.

While many people would contract radiation sickness and live, it is very difficult for the layman to determine whether an individual showing pronounced symptoms of radiation sickness has received a moderate, severe, or lethal dose of radiation. Moreover, acute psychological shock induces symptoms similar to radiation sickness, and vomiting - a symptom of both - is contagious in small spaces. Thus, someone who vomited would not know if he had received a moderate, severe, or lethal dose of radiation; if he had severe psychological shock; if he had vomited because of contagion; or if he had some other illness. This uncertainty about one's own condition and that of one's loved ones, and nausea itself, would increase the tension in a shelter. Moreover, nausea weakens people.(8)

It is difficult to be more precise in describing Lancaster County's encounter with fallout. We can only be sure that coping with the deadly radioactive powder would be an unprecedented ordeal, even if the social fabric and communications network remained intact. It is difficult to imagine the agonizing terror that would spread throughout the Garden Spot if the deadly dust began drifting into the county a few hours after the city itself were hit, as described earlier in this study. Lancaster City would only be attacked as part of a larger national scenario, which means that fallout would surely arrive here within hours.

AGRICULTURE

Lancaster County with its 5,000 or so farms leads all other non-irrigated counties in the U.S. in agricultural production. The Garden Spot ranks first in Pennsylvania in dairy, beef, poultry and swine production. We will note a few effects that a nuclear attack

(8)The Office of Technological Assessment, The Effects of Nuclear War, p. 86-87.

might have on agriculture in the county since it plays such a crucial role in the local economy. There are at least three ways in which nuclear war might affect agriculture.

1. Plants and animals would be destroyed by blast and fire in the case of a direct attack on the county.
2. Radioactive fallout drifting into Lancaster from other attack sites would also endanger plants and animals.
3. Either a direct hit or a blanket of fallout would cause massive disruptions in agricultural production.

The destruction of property and buildings described earlier in this report would affect farms as well. Barns, poultry houses and machine sheds near the edge of the city would be destroyed together with agriculture supply and food processing facilities. Other agricultural structures 5 to 6 miles away would suffer severe damage. The raging winds would flatten crops, silos and fences leaving surviving cattle to roam at will. Machinery would be tossed and blown about. Fire from the heat flash might ignite hay both inside and outside barns as well as dry crops and straw in the fields.

Beyond blast and fire destruction, fallout floating into the county would also wreak havoc on the county's agriculture. Animals could be injured by fallout in three ways:

1. exposure to fallout on the ground or on the roof of the barn,
2. exposure to beta radiation particles falling on their skin, and
3. internal exposure from eating fallout particles on pasture grass.

Larger animals experience radiation injuries much like humans. In general, horses and poultry are more resistant than cattle and sheep, and older animals can withstand higher levels than younger ones. Since most farmers don't have fallout shelters for their animals, many would undoubtedly die in heavy fallout areas. Any type of shelter for animals is better than none. Virtually all unprotected cattle would die if the outside radiation levels were 700 rem, but if confined in a barn, most of them would survive.(9) Eating the fallout is a very serious problem

(9) Radiation exposure to animals and plants is usually measured in Roentgens. This is not exactly equivalent to the rem (Roentgen-equivalent-in-man). However, considering the other uncertainties involved in the figures presented in this report, we will assume that one Roentgen is equivalent to one rem.

for grazing animals. If a herd of cattle gained access to a pasture 24 hours after the fallout arrived and the radiation were only 140 rems, they could eat enough fallout in the next 3 days to kill half of them.

Cattle exposed to less than lethal rates of radiation will show various symptoms of illness for several weeks which will stall their growth and/or production. Lactation periods may be reduced and often there is a temporary decline in reproductive capacity. Radiation exposure in the early stages of pregnancy might cause deformed and sterile offspring. The meat of surviving sheep, cattle and swine could eventually be used for human consumption under emergency conditions. However, concentrations of strontium-90 and iodine-131 in milk may make it dangerous for public use.

Plants in general are more resistant to radiation than animals, but they vary widely in their response to gamma radiation. A dose of 1000 rems would reduce a crop of peas by 50 percent, while it would take between 16,000 and 24,000 rems to do the same damage to squash. The range of sensitivity within a given species fluctuates greatly at different stages of growth. With corn for example, exposure to 1250 rems at about two weeks after it emerges from the soil would cut the yield in half, but it would take an exposure of 10,000 rems to damage the yield if the fallout came two weeks after the silk stage. Younger plants are much more easily injured by radiation than mature ones. Seeds already formed are rather resistant, but levels of radiation could produce some mutations. Radiation exposure may delay flowering and ripening so that tomato plants exposed early in the season might survive, but might not produce fruit by the end of the growing season.

The Office of Technological Assessment noted that our knowledge about radiation damage to crops is limited because we know very little about the effects of beta radiation on plants which might be 1 to 20 times the gamma dose. Food harvested from plants that were exposed to fallout could be eaten in emergency conditions if fallout particles were carefully washed off. Glasstone and Dolan indicate however that a "major problem would arise from the possible presence in the edible parts of the plant of radionuclides taken up from the soil by the roots or from particles deposited on the leaves." (10) They conclude that each situation would have to be evaluated individually, which would provoke a great deal of anxiety for the persons involved. Since, in general, the doses of the fallout radiation required to kill plants are much higher than those for livestock, it seems fair to expect that there would still be grass and forage crops for surviving livestock to eat.

The season of an attack would make a great difference in the effects on plants and agricultural production in general. A winter attack would do minor damage to plants, and radiation might subside

(10) Glasstone and Dolan, The Effects of Nuclear Weapons, p. 627.

enough that farmers could plant a new crop in the spring. The fallout from an attack in the spring, after most crops are planted, would kill the entire crop and the high levels of initial radiation would keep farmers inside, preventing them from replanting the crop. An attack near harvest time might not damage the plants, but the fallout might prevent farmers from harvesting the crop.

Beyond the direct damage to plants and animals from blast, fire and fallout, a nuclear attack on Lancaster or the presence of fallout would indirectly cause serious disruptions to agricultural production. Increasing technological dependence in agribusiness makes the whole industry quite vulnerable to the consequences of a nuclear attack. Poultry, swine and cattle no longer roam and graze at will but today are housed in huge animal "factories" with 50,000 chickens, 1200 hogs or 300 cows in one building. The huge herds and flocks in these modern facilities are very dependent on automation and electricity for feed, water, and ventilation. A direct attack on Lancaster County might paralyze water and electric supplies. The presence of fallout or piles of rubble might make it impossible to operate standby generators. Without proper ventilation, 50,000 chickens in a large poultry house would die within a few hours. The presence of debris or fallout would stop feed deliveries and product pickups. Would a farmer risk his own life in the presence of high levels of fallout to feed his 1200 hogs by hand, or to start a standby generator for a poultry house in the face of an uncertain future? Would we really expect a feed truck driver to jeopardize his own life to deliver 10 tons of feed necessary for the survival of 50,000 chickens? Probably not.

It is only fair to expect that thousands, probably millions, of hogs, cattle, and poultry would die, not from fallout injuries, but from a lack of water, ventilation and feed. Such widespread animal deaths would not only devastate agricultural production but would also create enormous problems for rodent and insect control as well as for the spread of epidemic disease for humans and surviving animals.

Without attempting to make precise estimates of the damage to Lancaster County agriculture, it seems clear that either a direct attack or fallout drifting in from other targets would at best sharply reduce our agricultural productivity and might at worst force us back to primitive methods. Ironically, it is the Amish, usually so far behind modern ways, that are best prepared for nuclear war, since their low technology agriculture might enjoy the speediest recovery after the war.

Perhaps the most disturbing aspect in estimating agricultural damage is what we don't know. The uncertainties associated with radiation entering the food chain and its long-term effects in soil and water are largely unknown. Beyond its effect on domestic animals, how would radiation disturb the balance of nature? Cockroaches are about 100 times more resistant to radiation than humans, and birds are much more sensitive than humans. Such wide ranges in resistance could alter

the normal ecological balance of plants and animals. All of these factors underscore, once again, the uncertainties surrounding nuclear war that are just as frightening as the things we do know.

SOCIAL AND PSYCHOLOGICAL EFFECTS

It is difficult to make precise estimates of the social and psychological ramifications of an attack on Lancaster, but the evidence from bombings on Britain, Japan and Germany in World War II, as well as Hiroshima and Nagasaki provide a solid base for projecting typical social and emotional responses to such situations. There is no reason to expect Lancastrians to act any differently. It is important to underscore as Katz has noted, that the psycho-social reactions to a nuclear attack will be more devastating than those from conventional bombing in three ways.

1. Scope. The magnitude of the attacks means that there will be very little immediate help from outside the attack area.
2. Timing. Conventional bombing raids usually stretch over several days or weeks and provide time to adjust and cope with the threat.
3. Radiation. The fear of the invisible "death dust" will paralyze behavior and intensify the psychological trauma.(11)

Limited damage, modest casualties, surviving leadership, external assistance - the usual resources surrounding a natural disaster such as a flood or tornado - will not be present after a large scale nuclear attack. Furthermore, Katz has pointed out that while the typical instinct is to move toward a natural disaster and help, everyone wants to flee from a nuclear explosion as far and as quickly as possible.

The psycho-social reactions described in this section would be present in varying degrees among Lancaster Countians regardless of whether the emergency came in the form of a direct attack, a massive evacuation or a blanket of radioactive fallout. The social disarray would be most severe if the crisis were a combination of all three. While we can not predict the severity of these manifestations, it seems certain that most of them would be present even with a small scale nuclear crisis.

(11) Arthur Katz, The Economic and Social Consequences of Nuclear Attacks on the United States, pp. 107-110.

Most Lancaster Countians remember the panic and uncertainty during the TMI incident in March 1979. As the news of the accident spread in the early morning hours, there was intense panic among many residents in the northwestern part of the county. Phone lines were overloaded and gas station lines were clogged. Adults frantically searched for children and spouses. Rumors were rampant. Children and adults held their noses so they wouldn't inhale the radiation. Should we evacuate or just stay at home? Will it help to pull the blinds? Can we believe the government officials? Who is telling the truth? Will our children be genetically deformed? The chaos and confusion of those few hours on Friday morning March 29, 1979 provide a tiny glimpse of the terror and confusion which would certainly be hundreds of times worse in the face of a nuclear attack.

Regardless of whether people huddle in their own basement to avoid radioactive fallout or in a host basement 50 miles away in Perry County hoping that their home survives, a nuclear attack of any sort will certainly shred the normal social fabric. Families will be split and the whereabouts of friends will be unknown. Telephones will be useless and gossip will be rampant. Information, if available, will be sketchy and continually changing. No one will know who to believe, and the normal symbols of authority may be gone. All of the components of social life which are normally "in place" will be shattered, making rational decision-making impossible. Moreover, a stable social system allows us to "know what will happen" so that we can predict and anticipate outcomes - a security which minimizes surprises. In the face of a nuclear disaster, most of the usual social systems that support our lives will be gone or dramatically changed. Surprise and fear will replace predictable routines. Fear will infuse social and emotional responses. When will the attack come? Will I ever see my children again? Will I die from radiation exposure? Will my children be sterile? Will an enemy occupation force arrive? Would suicide be better than what lies ahead? Uncertainty, surprise and fear will infect all aspects of life, distorting reality and paralyzing emotions and behavior.

The normal rules of social conduct that usually guide behavior will be suspended. Individuals in many cases will do things that they never would dream of in normal circumstances, refusing to help friends and neighbors, looting, stealing, violently forcing their way to the head of a food line; behaviors that would be considered criminal and antisocial under normal conditions. Mistrust, greed and exploitation will replace the norms of civility and concern for the public good. The evidence from World War II suggests that in extreme situations, behavior is primarily oriented toward personal and private goals. Community, national and social co-operation is rejected in the face of personal attempts to survive.

Role conflict at such a moment will be extreme. All sorts of people will be caught with the choice of looking after their own survival or fulfilling their public service roles. Will the policemen, emergency technicians, prison guards, gas station attendants and nurses in geriatric centers be willing to leave their families to perform their public roles in the face of a very uncertain future? In Hiroshima, even emergency medical units refused to respond and there was little spontaneous organization of relief efforts. When the social fabric is torn so drastically, normal social and moral obligations are dropped in the face of urgent demands for personal and family survival. Covering one's own basement windows with dirt takes priority over helping an invalid neighbor to safety. Without assurance that the community or nation will survive, why care about anyone else? Why share limited supplies of food even with friends? In Britain during World War II, officials discovered that many householders refused to lodge homeless evacuees.

The family unit will undergo enormous strain. Information about family members in other parts of the country will likely not be attainable. It may be impossible to find out about the welfare of members living a few blocks or miles away. Children or adults in the immediate family may be dead, injured or missing. Should one's own life be risked by searching for the missing? Death, injuries, loss of contact and forced separation will shatter the support that is usually found within the family, making personal survival even more difficult.

Housing and food shortages are likely to emerge as a result of an attack and/or evacuation. The widespread confusion and urgent need for supplies and medical treatment will likely necessitate martial law. Political authority in such a situation may be severely disrupted. Some leaders may have been killed, the normal political structure, at least on the local level, may be in disarray and the usual legitimate authority of democratic leaders may be gone. In such circumstances, it is difficult to predict the shape of political rule at either the local or the national level.

The pervading psychological response in all of this will be fear. The real and imagined threat from radiation will be overwhelming. How much radiation did I receive? Was it a lethal dose? Perhaps the effects won't show up for several weeks or years. Is it contagious? Can I touch other people who have been exposed? Will my body be contaminated forever? Can I drink water without fear? How do I know for certain that things are safe? Is there any way that I can get a clear cut verdict on my personal fate? What about my parents, children or friends - will they experience long-term disease or genetic mutations because of their exposure? Will my grandchildren be healthy? Will I ever be able to go outside again or eat any food and know for sure that it is safe? These may seem like foolish questions, but given the present awareness of the general public about radiation, they will be real questions, tormenting questions of life and death, in the aftermath

of a nuclear attack. The uncertainties surrounding the invisible presence of radiation will also take their toll in psychosomatic illness, as otherwise healthy persons succumb to fear.

Robert Jay Lifton has conducted extensive research on the psychological effects of the bomb among the survivors of the Hiroshima and Nagasaki attacks.(12) He describes several characteristics of those who remained. The suddenness and totality of death as well as the long-term taint of radiation illness left the living permanently immersed in death. Lifton calls this unusual psychological experience a "death imprint." Death was so unnatural, bizarre, indecent and absurd that it had no meaning. For those whose friends or family were near the vaporized center of the bomb, there were literally no dead bodies or graves around which to organize mourning rituals. Death itself loses meaning without ritual and without possessions to pass on. Death for a cause or in the normal course of things with appropriate ritual makes sense. But in Hiroshima, though the imprint of death was total and permanent, its meaning was vaporized.

Lifton also found a preoccupation with guilt. Among many survivors there was a sense that they had survived at the cost of someone else's death. Why were they singled out for survival? There was a pervasive guilt feeling, sometimes days after the attack, that they had not done enough to help the injured who eventually died. They had neglected public responsibilities, had refused to help even close friends, and had literally run away from the situation. In short, they had failed to perform basic human duties, had refused to help in the moment of crisis, and for this they were tormented with shame and guilt.

Another reaction was "psychic numbing," or "closing off" of emotional feelings and reactions. As a defense against the death imprint and guilt, survivors simply turned off their emotions so that they were psychologically dazed and stunned. Rage and sorrow were repressed. In Lifton's words, "if I feel nothing, then nothing is happening." The psychic numbing became an important coping mechanism - the only way many people could exist without falling apart.

Among others, hostility and anger erupted in their relationships. Anger at the enemy, at one's own country for inadequate protection and preparedness, at other ethnic groups competing for scarce resources and at anyone who might try to take the limited supplies first. Relationships were "touchy" and filled with mistrust and suspicion.

Finally, one might expect a general loss of hope in the face of nuclear disaster, for life's coherence and meaning are shattered. Collective and national pride, purpose and goals are in shambles. Have we really allowed this to happen? Is this the best that the human race

(12) Robert Jay Lifton, Death in Life: Survivors of Hiroshima, New York: Random House, 1967.

is capable of? The survivor's orderly symbolic universe is destroyed. There are no answers to the "why" questions and they are left with embittered world view. Even God couldn't have allowed such a thing happen. And so despair and hopelessness fills the air.

Such social and psychological reactions are normal when social worlds are turned upside down in a brief moment. The extent of these symptoms among Lancaster Countians will vary by the type and nature of the emergency, but they will be among us, and they will be real, whether in basement shelters in Elizabethtown, or among evacuees in Perry County. These are only some of the most obvious and immediate reactions to death, stench, destruction, radiation, martial law and dwindling supplies. One can only speculate on the long-term social and psychological effects of being stripped of jobs, titles, possessions, family, friends, and home.

LONG-TERM EFFECTS

All the effects which we have described so far will also have long-term implications. It might take decades to replace buildings and resources that were destroyed by the blast in seconds. People killed by blast or fallout might not be replaced in the society for decades. There are also other long-term effects which may not be seen for months or years after the attack. The consequences of such effects as genetic damage and changes in the physical environment are extremely difficult to project, but are nevertheless real effects of nuclear weapons with which Lancastrians might need to cope.

Although the survivors of Hiroshima and Nagasaki have been followed carefully, there is still great uncertainty and scientific debate about the long-term effects of ionizing radiation on the human body. Small doses of radiation which do not produce immediate illness can cause long-term harm, at least in a statistical sense. People in even the best fallout shelters and those on the fringes of fallout areas would receive at least small doses of radiation. Small levels of radiation might persist for years even though an area would be declared "safe" under emergency standards. Safety would become relative since many areas would not be considered safe for years according to peacetime standards. The long-term hazard would also be perpetuated as continuing rain brought light fallout back to earth at great distances from attack sites.

Some of the long-term effects expected from low levels of radiation include an increase in cancer deaths, abortions due to chromosome damage and genetic mutations. The deaths might be caused by cancer of the form of leukemia, or in the lungs, digestive tract, bones elsewhere in the body. Genetic mutations might double among populations exposed to a range of 20 to 200 rems. It is quite difficult to predict, however, how genetic disorders might emerge in later generations.

Office of Technological Assessment concludes its discussion of their findings with these comments.

1. Cancer deaths in the millions could be expected during the 40 years following a large nuclear attack, even if that attack avoided targets in population centers. These millions of deaths would, however, be far less than the immediate deaths caused by a large attack on a full range of targets.
2. A large nuclear war could cause deaths in the low millions outside the combatant countries, although this would represent only a modest increase in the peacetime cancer death rate.(13)

In recent years, considerable interest has focused on whether or not the explosion of a larger number of nuclear weapons might reduce the protective ozone layer covering the earth by as much as 30 to 70 percent. Such a "thinning" of the ozone layer could produce changes in the earth's climate and increase the ultraviolet radiation from the sun which might produce burns, skin cancer, and other dangerous ecological effects. Research in the last few years has raised doubts about the severity of the ozone depletion. Although there is less concern about this long term effect today, it has not been demonstrated that ozone depletion would not occur, and any depletion would raise the incidence of skin cancer. Thus ozone depletion remains one of the uncertainties surrounding the detonation of nuclear weapons.

Beyond the ozone problem, there is concern about the irreversible effects which many simultaneous nuclear explosions might have on the world environment. A major nuclear exchange might produce irreversible effects on the atmosphere, ecological system and food production. There is also concern that the radiation produced by a large-scale war might cause mutations in surviving plants and animals which in turn might alter the ecosystem in unpredictable ways.

In summarizing the long-term uncertainties, the Office of Technological Assessment concludes that it is not possible to estimate the probable magnitude of the damage to the earth's ecological system resulting from a nuclear attack.(14)

(13)The Office of Technological Assessment, The Effects of Nuclear War, p. 112.

(14)The Office of Technological Assessment, The Effects of Nuclear War, pp. 114-115.

The most startling conclusion that emerges from a consideration of these long-term and global effects is how much we don't know and how many uncertainties persist. This is particularly sobering in the midst of threats by political leaders to use nuclear weapons if they deem it necessary. It is impossible to predict Lancaster County's fate with regard to these long-term effects. It seems fair to say that such effects will have the greatest impact on our area if Lancaster is a direct target. However, as part of the earth's larger ecological system, we will share in the damages even if we survive a direct hit.

EPILOGUE

PREVENTING NUCLEAR WAR

We have described the awesome devastation that a one megaton nuclear weapon could bring upon Lancaster County and its people. We have tried to make the case that present world conditions make such events entirely possible and even probable. We cannot believe that American or Soviet (or Chinese or Israeli or Libyan) citizens would wish such destruction and death upon their own people or even upon their "enemies." Human aspirations, for the most part, are simple and universal: we want to go about our daily activities free of fear - working, playing, enjoying the results of our labors, and making a better world for our children.

The mere desire for peace, however, is not sufficient. If it were, we would have peace. We find, instead, that while the people and leaders of democratic and socialist nations alike proclaim the desire for peace, our governments pursue policies that move us ever closer to the brink of nuclear war. We must examine carefully the forces that propel the arms race - the so-called action-reaction cycle, the military-industrial complex, arms trade, the inter-service rivalries, technological challenges, national pride, and the Red-scare hysteria which frequently surfaces. We must recognize that they are human inventions rather than inevitable laws of nature. Although these social forces may be complex and difficult to deal with, they are not beyond our ability to comprehend or to control if we choose to.

There have been and will continue to be disagreements, not only among nations but also among individuals, as to how best to prevent the "final epidemic." We will not provide definitive answers to these difficult questions in one short chapter. We will, however, highlight what we consider to be some incontestable observations and offer some reasonable options and possibilities for the people of Lancaster County (and elsewhere) that could help to shape national policies so as to avert nuclear war.

DIAGNOSIS

The most fundamental observation, which all discussions of strategic nuclear policy must take into account, seems so obvious that it should not need repeating. Still, it is continually overlooked or obscured by detailed argument. Simply put, there is no defense against nuclear weapons - nor is there likely ever to be. Civil Defense and Crisis Relocation Plans might lessen the loss of life, but they will not diminish the destructive power of nuclear explosions, nor provide an escape from an attack that has already been launched. Neither can technology rescue us. Offensive capabilities will remain ahead of defensive capabilities because both superpowers constantly imagine how the other might someday defend itself against present weapons, thereby nullifying their deterrent value. Thus, both sides are already designing the next generation of offensive weapons to overcome the defenses that might be possible. In this way, the endless cycle of mutual threat and reaction goes on and on.

Without defense against nuclear weapons, there can be no true security as long as such weapons exist. True security can only exist in a stable world system where the threat to use nuclear weapons serves no useful purpose.

A second truth of the age of nuclear confrontation that is usually overlooked is that the institutions that we want to protect - even at the cost of nuclear war - would be destroyed in a nuclear war. Democracy, personal freedom, capitalism, free-enterprise (as well as communism and socialism) all depend upon a social fabric that has evolved through many generations. The institutions of modern civilization depend entirely upon multi-faceted and interdependent social structures. These social systems would be instantly obliterated in a nuclear war. Capitalism, for example, depends upon the profit motive. Without goods to buy, there is no profit motive. In a similar vein, democracy requires the expression of informed public opinion in order that the government may represent the will of the people. Without communication networks, there is neither information nor the means for expressing opinion in any way that it can be heard.

After a nuclear war when the paramount issues will be physical survival and the distribution of scarce resources to a few, anarchy or dictatorship will be the far more likely forms of government. We could not even expect a return to "normalcy" in our own lifetimes. It would take decades to rebuild the industrial, transportation and communication systems and the work force which allow the luxury of democracy. It has even been suggested that the present technological society might never rise again. The industrial revolution depended upon local, cheap energy and resources (wood, coal, and iron). As these were depleted, we exploited higher-grade resources (oil, non-ferrous metals) gathered from

remote locations around the world. These are now running out and we are turning to more exotic, synthetic materials and high-technology energy sources. It is entirely possible that in passing this way, we have so devoured the earth's resources - burned our bridges behind us - that we have made it impossible for civilization ever to pass this way again. High technology civilization and the life style it supports might be possible only once in the life of a planet.

A third truth that should be obvious is that world stability depends upon a more equitable distribution of the earth's resources. This means that American national security lies in relieving hunger, disease, poverty, and misery throughout the world rather than in securing ourselves against the coming assault from the have-not nations by enlarging our arsenals or by playing one nation against another. Nobody loves the bully and all will turn against him when given the opportunity. Our nation will be great by being humble and charitable and by evoking the best in others by example.

Finally, the arms race both weakens the free enterprise system as well as increases the probability of its destruction. The strength of the United States should be its economic and moral resources, not its military prowess. We fear Japan because it challenges us economically, not militarily. Ironically, Japan's economic strength lies partially in the small percentage of its Gross National Product that it has committed to military spending. The economic effects of the arms race are not at all subtle or obscure. Resources and labor expended to produce weapons are lost forever. One cannot eat or wear ICBM's. Such weapons serve no useful functions nor do they provide capital upon which industry can grow. Numerous studies have shown that a billion dollars invested in other industries would produce at least as many and often more jobs than a billion dollars invested in defense related industries. The present state of the economy, the high inflation rate, and the many unmet social needs are clear witnesses to the result of diverting vast financial resources to military expenditures rather than to basic human needs.

The military machine is a vast maw that clamors for ever more money and lives; it will never be satisfied. Our economy has been almost completely converted to a permanent, wartime economy. Weapons manufacturers are receiving the continuing assurances of Secretaries of Defense that their contracts will continue without serious interruption. All other federal programs "get the axe" while the growth in military appropriations exceeds the rate of inflation. What appears to be budget cuts in human services in reality turns out to be budget transfers from social programs to the military. We claim to cherish free enterprise and market place economics, but we have given these up for a government monopoly that produces nothing useful.

PRESCRIPTION

Describing the symptoms and diagnosing the ills of the world is far easier than prescribing remedies to alleviate the illness. Nevertheless, we shall offer some suggestions as to how we might help to prevent this final epidemic.

First, some changes in national policy are necessary. If there is no defense against nuclear weapons, if any use of nuclear weapons is likely to escalate to massive exchanges, and if the effects of nuclear weapons are as catastrophic as we have described, destroying people, resources, and the social fabric, how can the threat to use nuclear weapons advance any national interest? Such threats can, at best, deter an aggressor from using similar weapons against us, but they can gain us nothing. We are caught in the irony of threatening to "destroy the world in order to save it."

Because nuclear weapons can serve no useful purpose other than deterrence, the United States must immediately, clearly and emphatically stop threatening to use nuclear weapons either to advance national objectives or to influence perceptions of power. Other national policies must be adjusted to be consistent with this position. Although the world would be a more secure place with the total absence of all nuclear weapons, we do not advocate immediate nuclear disarmament. Desirable as this might be, it is too simplistic. The present strategic balance or standoff has been arrived at through a step-by-step historical process. The weapons systems, treaties, national policies, and alliances which have built this precarious balance are like a house of cards; the entire structure must be dismantled with great care, step-by-step, shoring up here while taking down there so as not to disturb the delicate balance. The strategic nuclear deterrence will begrudgingly need to stand until alternate means are developed to ensure world stability and security.

Admitting the present necessity for strategic nuclear weapons as deterrents only, we should ask what numbers and types of weapons will be sufficient for this cause and then limit our nuclear arsenal to only these weapons. As we have shown, overkill capacity generates new dangers without providing any additional security. One group of scientists and students of military affairs has argued convincingly that the vulnerability of our land-based missiles is best responded to by dismantling them instead of initiating a costly program of developing new missiles (MX) and placing them in hidden or hardened silos that would soon become vulnerable.⁽¹⁾ Our submarine-based missiles alone are sufficiently accurate and plentiful to deter attack. Their mobility provides a natural protection that will remain for a long time. By

(1) The Boston Study Group, The Price of Defense.

removing our land-based missiles we could increase the stability of Soviet-American relations by eliminating a first strike threat and at the same time strengthen our economy without diminishing our nuclear deterrent in any significant way.

Other national priorities must be reoriented toward securing world stability rather than toward increasing and projecting an image of world power. We must seriously and conscientiously seek arms control agreements with the Soviet Union and other nations. We must abandon such useless concepts as nuclear superiority. Consistent with deterrence, we should pledge not to be the first nation to use nuclear weapons - a pledge which the U.S. has always refused to make. We should remove cruise missiles from Europe and stop threatening to use Europe as a nuclear battleground. We should stop arming Third-World countries and increase our development aid to them instead.

In the context of new national policies vis-a-vis the Soviet Union and world stability, we must foster new images and perceptions of the Soviets. We must reject the cold war demagoguery that finds nothing good in the Soviets (and nothing bad in the Americans). The Soviet Union is not the source of all political instability in the world as the present administration has frequently proclaimed. Such statements from government officials and our belief in them betrays our willingness to dehumanize the "enemy" and does not fit the rational and moral self-images we like to maintain as a nation. We may not trust the Russians and we may want to blame them for creating this dangerous situation, but such impulses will never get us out of this predicament. A historical analysis of the arms race shows that the burden of guilt must be mutually shared by both Americans and Russians. Independent observations of international affairs suggest that neither the Russians nor the Americans can be trusted.

Our survival requires that we react more rationally with regard to the Russians, recognizing that the prevention of nuclear war is our mutual goal. We must understand that we will not increase our own national security by threatening the security of the Soviet Union. We must cease linking arms control agreements that are clearly in our favor to other Soviet behavior that we dislike. We are not suggesting that the Soviets will immediately change their policies and join us in some great crusade for peace. The Soviet Union is likely to continue to intervene in the internal affairs of many nations (just as we have also done and will likely continue to do) in an attempt to influence the balance of world power. Because many of our past differences will change only slowly, if at all, most Americans will probably not learn to love the Russians, but we must learn to live with them and we must stop acting against our own best interests just in order to "spite" them.

In addition to changing some national policies and our perceptions of the Russians, we must be willing to re-examine and, if necessary, revise some of our cherished perceptions of ourselves and our role in

the history of the world. We must look forward to a planetary or global society and seek our national destiny in the future rather than just in the present and the past. What are our aspirations for all human beings on this planet? Surely, these include health, political justice, freedom from hunger, freedom of the spirit, a society in which we can enjoy the results of our labors and the opportunity to contribute to the common good. These are not exclusively American or capitalistic or even democratic ideals. How do we accommodate cultural, religious and ethnic diversity? How do global societies function and thrive? Even the concept of the nation-state itself must be scrutinized. Its very nature demands that whatever resources are available must be used to preserve it. Is this preservation worth the cost if the cost is nuclear war? The nation-state has not always existed in history. Perhaps the global society has evolved to the point where the nation-state has become obsolete. What shall take its place? The change from a parochial to a world view will not come easily; yet it must come if we are to survive.

Change national policies! Change our perceptions of the Russians! Change our perceptions of ourselves! Seek a national destiny in a future global society! What does all of this have to do with Lancaster County? We believe that world events are not entirely beyond the control of people. That, after all, is what democracy is supposed to mean. Democracy requires, however, that we work diligently to ensure that our government, acting on our behalf, acts in our best interests. We must make sure that our government is acting to prevent rather than to encourage nuclear war and is spending our national resources wisely and consistently with the best qualities of the American character.

To do our part, above all requires that we be informed. This is not difficult with respect to nuclear war. The basic and essential information about nuclear war is not classified as one might expect. Through private and public discussions and by reading publications such as this, we must increase public awareness of the issues surrounding nuclear war. If we are informed and speak out, Congressmen, Senators and Presidents will not be able to ignore our sentiments. Congressmen from the 16th District (Lancaster County) have for the most part an enviable record of representing what they believe to be the wishes of their constituents. If their perceptions of our best interests vary from our own, then it is our right and duty to inform them otherwise.

PROGNOSIS

National leaders may nudge political processes slightly one way or another by appealing to our better or worse natures and many aspects of world events beyond American control all too frequently do substantially influence our national actions. However, the nation seldom follows policies that are inconsistent with prevailing public opinion or, if it does, such policies do not persist very long. Because this is true, we must look to the grass roots for the signs which fortell our nuclear future.

The signs, as always, are mixed, but not altogether discouraging. There is no doubt that the general consciousness of nuclear war has increased during the last few months. Small but persistent public action groups such as SANE, Council for a Liveable World, The Federation of American Scientists, and the Pugwash Movement have existed with little notice for many years. More recently, however, their activity has intensified. The Council for a Nuclear Weapons Freeze, now circulating a petition calling for a freeze on nuclear weapons production and deployment, is operating in 48 states and has the endorsement of 18 congressmen and several national church organizations. Ground Zero, a national coalition that has received endorsements from the National Council of Churches, the American Association of University Women, and the United Auto Workers, is planning "teach-ins" in as many as 100 cities during April 1982. The Physicians for Social Responsibility, after several years of dormancy, has reawakened with a call from Dr. Howard Hiatt, Dean of the Harvard School of Public Health, to help to prevent the "final epidemic." Local chapters of the Physicians for Social Responsibility have spring up all over the country, including one in Lancaster County. There is an increasing awareness of the seriousness of this issue in church groups and on college campuses. 250,000 people marched in a demonstration for nuclear disarmament in Bonn in October 1981 and similar large-scale marches took place in London, Rome, Brussels, Paris and Oslo. Several of the major television networks have devoted major efforts to documenting this ominous threat. Newspapers, magazines, and professional journals in various academic disciplines have paid increasing attention to the topic. These are good signs - signs that some recognize the threat and are willing to try to do something about it.

The International Pugwash Movement recently publicized a pledge submitted by one of its donors. It captures succinctly our present condition and one person's response.

I, Jack Boulogne, hereby promise to support the cause of world peace with all the effort and money I can reasonably spare. I will not donate money to any other charitable cause or political movement since these lose all meaning in the event of a nuclear holocaust. I will, instead, support that one cause that may make all the other causes relevant again.

Even though we may not subscribe to the precise wording of this pledge, each of us does have a choice. We can confront this common peril we face and commit a significant portion of our lives to seeking peace or we can turn away from the problem out of fear or apathy. If we choose to live in fear or apathy, we may well die in fear or apathy. If, on the other hand, we choose to live and work persistently in hope, it may just be possible that nuclear war can be averted.

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